

FIRST ACADEMIC CONFERENCE ON THE SUSTAINABLE DEVELOPMENT GOALS "WHY IT MATTERS" AS PART OF THE DECADE OF ACTION

PUBLICATIONS volume l SDG1 – SDG7

UTAH VALLEY UNIVERSITY OCTOBER 5 – 7, 2022







United Nations

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Preface

The Sustainable Development Goals are a universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere. The 17 Goals were adopted by all UN Member States in 2015, as part of the 2030 Agenda for Sustainable Development which set out a 15-year plan to achieve the Goals. They are unique in the world due to their historical nature, since never before had such a large international consensus been achieved linked to a collective roadmap; universal since they include all kinds of countries and people; detailed thanks to the different levels and execution indicators; and transformative because they invite us to ambitiously transform our societies.

With just under ten years left to achieve the Sustainable Development Goals (SDGs), world leaders at the SDG Summit in September 2019 called for a Decade of Action and delivery for sustainable development, and pledged to mobilize financing, enhance national implementation, and strengthen institutions to achieve the Goals by the target date of 2030, leaving no one behind. The Second SDG Summit, that will take place on 18 September 2023 will review the status of the global implementation of Agenda 2030, paying particular attention at the work carried out at the supranational level.

The UN Secretary-General called on all sectors of society to mobilize for a decade of action on three levels: global action to secure greater leadership, more resources and smarter solutions for the Sustainable Development Goals; local action embedding the needed transitions in the policies, budgets, institutions and regulatory frameworks of governments, cities and local authorities; and people action, including youth, civil society, media, the private sector, unions, academia and other stakeholders, to generate an unstoppable movement pushing for the required transformations.

We are at one of the greatest crossroads in recent history. We live immersed in a systemic change in which the classic geopolitical conflicts linked to territorial sovereignty and resources have returned to the international reality, overshadowing the possibility of reaching and maintaining consensus around our shared challenges as a humanity. The world has also in recent times witnessed the devastating consequences of a pandemic that has highlighted and exacerbated inequalities across the globe, particularly for communities and social groups already vulnerable, notably women and girls. The gap that exists between the so-called developed world and those developing nations and economies in transition has widened and, once again, demonstrated that it is imperative to address global challenges through a common agenda. Never has multilateralism been so important in finding solutions to our social challenges.

It is precisely this complex context of confrontation and socioeconomic differences that should encourage us to strengthen our commitment to the 2030 Agenda as a universal language from which to build a social contract that leaves power competition aside and reactivates the path towards universal, inclusive, and sustainable development. The most prosperous societies are the most integrated and cohesive, those that share a social contract of basic principles, values, and priorities. At the current global crossroads, this is an even greater need, and the 2030 Agenda is a universal reference.

The 1st International Academic Conference on the Sustainable Development Goals - "Why it Matters", co-sponsored by the United Nations Department of Global Communications through the Civil Society Unit and the Academic Impact Initiative , takes place as the Decade of Action continues the countdown towards 2030, and the global community, including academic institutions, civil society organizations, private sector entities, local and national governments, as well as media outlets, explore ways through which the implementation of the 2030 Agenda and the 17 Sustainable Development Goals become an intrinsic part of their efforts.

Academic institutions play a crucial role in these efforts, as they are uniquely qualified to bring to the table discussions and approaches that can be incorporated into the action plans in other social sectors. This publication gathers some of the contributions around the relevance and pertinence of why the Sustainable Development Goals and the 2030 Agenda matter more than ever before.

These intensely negotiated agreements offer the academic community a clear and unique development framework that invites everyone at all levels of society to work to transform our world and create a more equal and sustainable society for everyone. Inspired by the "Why It Matters" motto these two volumes collect the effort of reflection and scientific research, in the spirit of social commitment and inclusivity, and represent a proposal to transfer experiences and good practices to the global society.

There is still much work to be done, and we hope that this publication will contribute to the conversations in preparation for, but also part of, the 2024 Summit of the Future convened by the United Nations, and described by Secretary-General Antonio Guterres as "once-in-a-generation opportunity to reinvigorate global action, recommit to fundamental principles, and further develop the frameworks of multilateralism so they are fit for the future."

In putting this collection together, our goal has been to inspire others and provide a unique and first-of-its-kind compendium of academic works aiming at healing through sustainable approaches our ailing planet and its peoples, building a world for all to enjoy.

Only working together can we make a difference.

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The Mukono Micro-Livestock Farming Project Designed to Tackle Sustainable Development Goal No. 1, No Poverty

Awath Java Abdat, Babirye Esther, Emmanuel Kato, Kuteesa Jesse Kirule, and Owen Ssembuya (Uganda)

Abstract

41% of Uganda's population live in poverty according to the Uganda Bureau of Statistics (UBOS). Almost half of Uganda's population is under the age of 15, representing one of the youngest populations in the world. A young population indicates high potential but as the situation stands, poverty is high amongst the households that 45% of children drop out of school at primary level but the rate is speculated to be higher for girls. Not to digress, this problem amongst many others is the reason why poverty has been persistent in the Ugandan society. Our Team chooses to tackle the SDG Number 1, No poverty to see to it that such problems are done away with. The aim is to create a society that is financially independent and financially secure hence sustainable in the long run. The Team chose to work with a project that is easily executable and understood by everyone and that was micro-livestock farming, with cuniculture being the pioneer of this project we called the Mukono Micro-Livestock Project. The cost of setting up the project is not very costly, and the maintenance of the whole project depends on how its ran. Given our major aims, to conclude this project we decided that SACCOs are the way to go, with everything else being just a means to an end. This submission shows how effective the project can be and with funding, it will surely change the lives of people in the target area.

Keywords: Kigezi Health Care Foundation (KIHEFO), Mukono Micro-Livestock Project (MUMILI), Saving Credit and Cooperative Organization (SACCO), Sustainable Development Goals (SDGs), Uganda Bureau of Statistics (UBOS), United Nations Development Program (UNDP)

Introduction

In Uganda's context, poverty is locally defined as the lack of necessities such as food, shelter, clothes, education, and Cash, which are greatly seen as the major challenges in communities. The poverty line in the country is US\$0.88 which is much less World Bank international figure of US\$1.9. The focus area is – which is in Mukono District, Namubiru Village. The SDG 1 No Poverty aims at halting poverty and if its successfully halted, most if not all SDGs are to be done away with. This is because in all the different SDGs developed by the UN, poverty sits at the heart of it all. Poverty breeds ignorance and from that comes all the other sins and atrocities since in scenarios where survival is the major obligation, the animal in man comes out and trembles the "human rights" without a flinch in thought. Only people who have secured a financially stable environment have a chance to develop other aspects of life. On the contrary a survivor's purpose is to live another day, a mind with only a singularity like that cannot think of education, cannot think about gender equality, cannot care about sustainable energy sources, a mind like that even

worries less about climate; not to mention all the psychological trauma that may come with it. What we are trying to point out is that it is illogical to ask a mind that lives to survive to look beyond the basic needs of life and pursue other ideologies and we dare say that Poverty is the root of all evil. The sustainable development Goals (SDGs) are the key to a better world as addressed by the United Nations. The team is focusing on SDG NO.1 which is "No poverty, to end poverty in all its forms everywhere."

As all other countries, the economy suffered a great blow as a result of the Covid-19 pandemic, and this worsened the already bad financial status of many Ugandans. Basing on our project site Namubiru village, Mukono district central Uganda, the state of poverty has steadily increased following the negative Impacts of the pandemic covid-19 where most individuals lost their jobs due to the decline in the country's economic activities, but it was on record that the agricultural sector of the country was less impacted. In the first half of 2021, Uganda's Finance Ministry reported that 28 % of Ugandans were poor. That rate had increased from 18 % before the pandemic. In line with World Bank practice, the official poverty line is the equivalent of \$1.90 purchasing power per day and head. The Finance Ministry also noted that two thirds of Ugandans had lost at least some income due to the Covid-19 crisis. It was obvious that things would be challenging. In June 2020, the Uganda office of the United Nations Development Programme (UNDP) prepared a report on what impacts the novel virus was likely to have. It expected some 4.4 million workers in Uganda's informal sector to fall into extreme poverty. Women, people with disabilities and chronic conditions, youth and the elderly were said to be most at risk. The UNDP report also predicted that tourism, manufacturing, and services sectors would be disproportionately affected. Even before the pandemic, Oxfam, the international charity, had warned that inequality was worsening in Uganda example, that 80% of rural households were vulnerable to poverty even before Covid-19, compared to less than 30% in urban areas. The team after researching and discussing the best way to tackle the task at hand concluded that being part of the agricultural sector would be a nice start. The decide project plan was microlivestock farming with the overall aim to establish a financially secure and independent society through savings groups (SACCOs). Sustainability means the state of being independent of help from others, this is exactly what the Team wants to achieve, and that's why we choose a project that can make people financially free and secure, hence, sustainable. This means the challenge at hand is difficult with objectives like mindset change and development of money management skills. The choice of livestock was poultry and cuniculture (rabbits). It may not seem like much but with research we found that the products of these two commodities are both high and the later had a relatively young market with lots of room to grow.

Under the project we decided to name the Mukono Micro-Livestock (Micro-livestock are animals that require limited space to rear hence there is no threat to the environment and climate at large) Farming Project, the aim is to create a society with financial independence and financial security. Financial independence is the state where one has income that he or she is free to spend on things that interests them. Financial security is simply a fall back plan for finances during a crisis. These two, working hand in hand, can without doubt end poverty and can be sustainable. With products coming from the animals being the main source of income, and SACCOs being the form in which finances are secured. The major resource we are to optimize is the human resource, the

participants themselves. The stakeholders need to be willing to learn and accept the terms at which we are a going to be operating with.

Purpose

The MUMILI Project is designed for strictly purposes of freeing the society of Namubiru from staunch poverty and acquire middle class income statue. This is to be done by the involvement of 50 participants from the target community, training them the disciplines of rearing the respective animals and also educating and involving all the participants in SACCOs with a common product. But what is a SACCO? In full, SACCO is an acronym for Savings and Credit Cooperative Organization. SACCOs are voluntary associations where members regularly pool their savings and occasionally obtain loans which they use for different purposes. The general idea is to promote savings and make credit available to all members, talk about being sustainable. Normally, SACCOs operate on a basis of equality for promotion of economic interests, group ownership of property and resources acquired through these cooperatives is also acceptable since people have equal stakes and usually, SACCOs comprise of members in the same income statue to avoid some members from acting privileged. SACCOs are democratic and have in many areas of the country helped to be an effectively participatory strategy to bootstrap low-income individuals into the socio-economic activities of the nation. Also, they reduce exploitation of powerless individuals by other individuals or institutions. With all the above being explained, other questions arouse, how are members going to join the SACCOs? Where does one get the income to keep up with a SACCO?

Well, the project is designed in such a way to be self-sustainable, by this we mean that steps were taken to see to it that work is resourceful and yields results i.e., in these SACCOs, only members of the MUMILI project will have permission to join and only if they are registered and have yielded results from the respective fields of the micro-livestock project. This will help promote unit amongst members and also avoid interruptions from outsiders with little understanding.

What we are trying to describe is the methodology that will get us to the aims of financial independence and security. Members carrying out the project, after 6 months of operation will be introduced to the market. After earning from their own product, they will be inclined to startup different SACCOs in-order to further broaden their knowledge and influence over the area. Using them as an example, the team will see to it that we attract more people from the same area.

Why Micro-Livestock?

The state in which most people in the area of Namubiru live is that of extreme poverty, and as for that matter, the team chose a more financially friendly solution, cuniculture and poultry. These two farm animals are not as hard to rear as say cattle. The main challenge with them is sanitation, and we believe with proper sensitization, anyone can learn how to handle them. The second reason is due to the fact that they don't require a lot of space and resources especially for starters as compared to other animals. One of the major driving factor for choosing this program is that, for rabbits, there is a higher level of output of products i.e. the gestation period of the rabbit female

is 30 days, and a litter at least has 7 kits; Proper breeds mature within 5 months making the rabbit a highly profitable animal when it comes to turnover (Mukasa, 2021)."One can start with only six rabbits (Mutua, 2016). In the beginning, I was the farmer, I was the vet, I was everything. I was small, but I had a big vision, a serious vision," Mutua reminisces. Unfortunately, his vision was one that was often met with ridicule. "If you tell people, 'Raise rabbits, there is a future,' they will tell you, 'No, rabbits are for kids.' It's challenging to change somebody's tastes. The Masai (a tribe in northwest Kenya) give rabbits to dogs. I spent two years going to trade shows and giving away rabbit meat for free, saying, 'Taste this!'' (Mutua, 2016)

With MUMILI, one can easily understand the full scope, from what they will be doing, how they will be doing it, how to earn, and how to keep earning. It secures the stakeholder. In conclusion to this question, all we are describing is that; one joins the project, rears the animals, takes the products from his own farm to market and gets the profits, then with those profits the registered members join a SACCO. It is under the SACCO that our major interest lies because as a cooperative society, the scope of one's economic activity is enlarged, both individual and on a group basis. We ought also to point out that MUMILI project can act as both a source of income and food to whoever becomes involved since the products are edibles. To add on, the waste material from both poultry and rabbits if collected in huge sums has high market value since it's a capable fertilizer. Also, the wool of the rabbits is also marketable. Given the fact that the market is still developing for the rabbit products and on high demand, the possibility of a highly productive supplier to set his/her own price is high (Mutua, 2016). And as a matter of fact, the price of rabbit's meat has a range, 25000 -35000 Ugandan shillings.

"If you want to feed your family, you can buy one female and one male. Keep the first two rabbits until the pair matures, around five months, and after that the breeding speed of the rabbits keeps up with the eating speed of the family. You will always have enough meat," boasts Mutua. "If you want to do it commercially, you'll need at least five female rabbits and one male rabbit. That can earn you USH 640,000 [\$200] or even up to USH 1,280,000 [\$400] per month." To put that in perspective, USH 640,000 is already more than many manual laborers in Uganda.

According to the Food and Agriculture Organization (FAO) of the United Nations, <u>rabbits convert</u> <u>20 percent of the fodder they consume into protein</u>, making them roughly twice as efficient as cows. They're also about as low-maintenance as livestock can be; they thrive with minimal space and virtually no attention. While more demanding farm animals require valuable cereal grains, rabbits will happily munch away on just about any greenery you throw their way. And unlike cows, which give birth only once a year, these little guys breed like, well, rabbits, producing litters of roughly eight kits at a time. A project such as ours can actually be used to tackle two SDGs that is; No poverty and Zero Hunger as the research provided above has clearly shown such potential. For poultry, chicken in particular, if one majors in the local breed (breeds indigenous to Uganda) the risk of disease is decreased. Although this comes at a cost of time, the products(eggs) from these breeds have a price that triples that of the usual layers that are imported. Being local breeds, these birds are more.

Methodology

The execution of this program must have proper management of all aspects from people to funds. The way the team worked around this was to acquire a project site. A base of the first operation so as to act as the body that links the collective goods from the participants to the market. The level of hierarchy at the site will be democratic and imitate that followed in a SACCO with few adjustments from the experts we are to involve along the way. The project site will of course be within the target area so as its easily accessible to those who would be interested. The project site will also act as a place where the civilians would get all the training and information required to get involved into the project.

We are to make it clear through paper work and orally that whoever chooses to join our expedition is bound to join a SACCO. This is to ensure results from the farming practices and also help clarify that the major aim is financial independence and security. Well as involvement into the program will certainly bring income, for the equation to be complete one needs to join a SACCO for the equation to be complete. This is because a SACCO improves ones social network and makeup money needed for emergencies. Better decision making is therefore paramount and a member can rest assured that he has a backup plan. According to a study conducted by the Uganda Technology and Management University in 2017, in Uganda, savings and credit cooperatives (SACCOs) as financial intermediaries, channeling savings into loans, provide saving opportunities for the people, especially in the rural areas, but further improvements are necessary to make their services more efficient and sustainable.

A study done in Kampala by Makerere University found out that SACCOs have significantly reduced poverty, contributed to education, helped in saving mobilization, and provided emergency housing loans and funeral insurance. SACCOs were found to have contributed to strengthening social protection and social inclusion, reduction of risks and vulnerabilities facing women entrepreneurs and ability to make decisions. Inclusion of women workers and women entrepreneurs with disabilities, increase in responsibilities in the home and the ability to participate in the community activities, helping women to network and build relationships.

According to the research made from the different surveys we made across the target society, it was brought to our understanding that starting with places of worship like churches would simply make our work easier to get recruits. Not surprisingly, we got a good turn up of people who were interested in the project. Further surveys revealed to us what we proved us to be on the right track as we found many of those interested were actually carrying out cuniculture already. What more signs did we need to be confident, for one thing was made clear to us and it was that people were actually interested, they only lacked proper training and serious motivation. Those who were involved in the cuniculture lacked the proper facilities to enlarge their animal numbers as they would die off easily due to poor sanitation. This would kill motivation for many, not to mention that it was a hobby to some and yes, once in a while they used them for food. The other problem was the market. Markets for product such as these prefer large numbers of products, and require a steady flow of product within intervals. For example, some suppliers mentioned that on a monthly basis a farm ought to produce over 200 animals (Mukasa, 2020) This requires that one fully

commit to providing to the market with a sustainable source ensuring a steady flow of income and products for both supplier and buyer. To put it simply, people who do small scale are bitterly not able to access the full potential of this market share, but if all the people of the area have one single place (the project site) to work as the middle man between the market and the farmer, everyone is able to have a share of the full potential of the market.

Assuming all goes well, and we actually achieve our first goal of hitting the market in the first 6 months of our operation, the profits that will come off the success will be used for SACCO registration from all the first participants without exceptions. SACCOs are given an annual probation for operation.

Relevant Literature

In October 2013, The Kigezi Healthcare Foundation (KIHEFO) opened the Rabbit Breeding and Training Centre, in Kabale, Uganda. With 120 rabbits for breeding and distribution the project began giving to poor households and currently has 700 rabbits housed at the main center-with capacity for 3,000-and additional rabbits distributed to more than 60 farmers within the region. The main center located in Kabale-town is now fully functioning and has 16 breeding cages, 60 weaning cages and 1 mobile rabbit cage for demonstration with community members. Rabbit training manuals have been designed in both English and Rukiga, the local language. since the start of 2016, more than 800 people within the community have been trained in rabbit rearing and management and equipped with skills and knowledge about the benefits of keeping rabbits. The success of this project has spread since then and mini-breeding centers have been built in 6 additional communities, including Bukoora, Muyumbu, Rubira, Nyabikoni, Kasinde and Ikumba-all in Kabale district.

In October 2015, Trina Moyles, a KIHEFO volunteer, visited 6 farmers who'd benefited individually in August 2014 with 1 cage (4 units) and 3 breeding rabbits. She reported that "one farmer had tripled her meat intake over the course of 14 months. Farmers were eating the rabbits, and also selling them to generate income. It was a balance of eating/selling. An unintended outcome was the amount of rabbit manure produced, which was used to make compost for their field crops. Another unintended outcome was that some of the rabbit farmers were organizing amongst themselves-donating rabbits to other farmers who weren't necessarily direct beneficiaries of the original project."

Limitations

All projects face limitations and problems that threaten their success. The MUMILI faces a few like these but they can be dealt with the most serious limitation in our project is the project site. Well as the participants can do the work from their homes, the whole operation of connecting them and training them needs a center of command, a base of operation. This site is where the local participants will have to bring their products so as we can put out to the market. What we are trying to point out is that the project site will be the place where animals are slaughtered in huge quantities and delivered to the meat market. This is because the market has a lot of demand

and obviously a single farmer cannot meet the weekly demand but as one unit, receiving from all over the village, the MUMILI project site can act as the middle man. To add on, the setting up of the different infrastructure is also sophisticated. The greatest expenses are used up by the wood for the modified hutches that are needed to run cuniculture (Mukasa, 2021).

The other would be limitation is disease but with proper training, a farmer can raise the animals in a clean environment and not worry about disease. Also, the best way to fight against coccidiocis, the most notorious disease towards the rabbit's life is immunization. This can be done by mixing coccidiostant in the feeds of the kits during the weaning period. This is information got from experts we tried to interview.

Conclusions

In conclusion, the MUMILI project has a high success rate if it gets sufficient funds to setup all the required infrastructure and carry out requires sensitization of the people in the area of focus. It ought to spread through different communities across the country and more projects like this can be developed to help fight poverty amongst Ugandans. It should be noted that the major goal/aim is to create a financially stable society, with the attributes money security and independence. The project described above also shows the potential of handling two SDGs namely; No poverty and Zero Hunger. This is because the products can be used for both commercial and nutrition services.

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The Socio-Economic Effects of Child Marriage on the Wellbeing of the Girl-Child: An Analysis of the Implementation of Agenda 2030 in Cameroon

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Abstract

Socio-cultural and customary laws in Cameroon perpetuate child marriage, given that the civil and common law operate alongside a strong under-current of customary laws¹ which sometimes act as a parallel regime to statutory law, thereby compromising the development (SDG 1, 3, 4, 5, 8, 10, 16) of girls, resulting in early pregnancy, social isolation, little or no education, poor vocational training/skills, loss of self-esteem and reinforces the gendered nature of poverty. Indicating that boys are also affected by child marriage, but the impact is severe on girls, compounded by the fact that Cameroon has not adhered to Article 6 (b) of the Protocol to the African Charter on Human and People's Rights on Women, which states a minimum age of marriage at 18 for both boys and girls. Religion is often used to justify child marriage in Cameroon and elsewhere. This explains why it is predominant among the Muslims in the Northern part of Cameroon, where young girls are still sent into marriages with traditional rulers, lamibes, who may have ten or fifteen wives. This practise is also common among the Bacheve, Oliti and Assumbo clans in Akwaya where girls at five, unknowingly are faced with the reality of child marriage at about the age of ten when their supposed suitors come for them.

This paper examines the socio-economic implications of child marriage on the well-being of the girl Childs' education, health and development through documentary and desktop review of literature and concludes by proposing recommendations for ways in which the practice of child marriage can be addressed through the Ministries of Women's Empowerment and the Family, Social Affairs, NGOs/CSOs and other stakeholders in Cameroon.

Keywords: socio-economic, child marriage, wellbeing, girl-child, agenda 2030, development in Cameroon

Purpose

Child marriage is gendered, it affects girls in much greater numbers than boys considering that in primitive communities, an unmarried person as old as seventeen and eighteen was regarded as inadequate, irrespective of whether the person was a boy or girl (Plan International 2013 & Lewis

¹ Customary law is part of Cameroon's law pursuant to the provisions of section 27 of the Southern Cameroons High Court Law 1955, indicating that the High Courts shall "observe" and "enforce the observance" of customary law insofar as it is not repugnant to natural justice, equity, and good conscience or contrary to the written law. Despite the illegality of child marriage (forced marriage) under section 356 of the Cameroon Penal Code and its negative impact on development it is still tolerated in the name of culture (Cameroons New Gender Policy Document: 35).

1982). Although indicators 5.3.1 of SDG 5 measures child marriage among girls, the practice occurs among boys as well perpetuated by gender inequality and unbalanced power relationships at all levels of the society. Child marriage refers to both formal marriages and informal unions in which a girl lives with a male partner as if married before the age of 18 (Arinze-Umobi 2008; UNICEF 2005). In child marriage the consent of the child is ignored and her parents enter into agreement for her. This often also constitute forced marriage and coercion, given that, children under 18 cannot make informed decision on whom to marry.

Although the United Nation (UN) defines a child as anyone under the age 18, there is no single definition of the term "child" worldwide and there are variations within countries. That is why in some countries a girl is only a child until she begins menstruation and is interpreted as a marriage of a girl who has not yet reached puberty. This explains why some organisations refer to child marriage as "early or forced marriage". Therefore, forced marriage in this context refers to a marriage "conducted without the valid consent of one or both parties and is a marriage in which duress – whether physical or emotional – is a factor" (United Kingdom Foreign and Commonwealth Office in Linonge-Fontebo 2018).

According to Judiasih, Sudini, Rubiati, Yanitasari, Kusmayanti & Salim (2019), Al-Qu'ran does not determine a concrete age limit for someone or party who is going to get married. Age is not one of the legal requirements for a marriage. An-Nissa verse 6 "... test the orphan until they are old enough to marry, and if in your opinion they have been intelligent, then give up their possessions". Based on these provisions, experts stipulate that a person is held accountable for his actions and has the freedom to determine his life after being of sufficient age. A child is considered an adult when he is aqil baligh in Indonesia. Therefore, children who have reached a certain age can distinguish between good and bad. There is no explanation about the exact age when someone is considered an adult to Islamic Law- it is based on maturity on men and women themselves. Fear of falling into adultery which is a taboo pushes people to marry. In other context, child marriage is rooted in gender roles and social expectations, prevailing conceptions about Islamic law, and the fear of falling pregnant before marriage. This is common in the Northern regions of Cameroon where religion and culture prepare the girl child for marriage rather than schooling for chastity.

The goal of Agenda 2030 for sustainable development is gender equality and women's empowerment and was adopted by the United Nations General Assembly on the 25-27 September 2015 and centered on 17 SDGs which became effective on 1 January 2016 to complete what the 2000 Millennium Development Goals was not able to achieve in fifteen years. This paper therefore provides an analysis of the relevance of each of the seven targeted SDGs used and its potential for women's contribution towards it achievement and establishes the extent to which child marriage affects the socio-economic wellbeing of the girl child. Purporting that a violation of women's human rights through gender inequalities to economic growth, health, education in Africa and elsewhere where child marriage prevails will hamper SDG.

Literature provides that each year, 14 to 15 million girls are married before the age 18 (UNICEF 2012 & UNICEF 2018). The consequence of girls marrying early is that they drop out of school,

have more children and are at greater risk of HIV infection and intimate partner violence and face serious health complications and even deaths as a result of early pregnancy and childbearing. Child brides are often widowed, isolated/abandoned and divorced with limited opportunity to participate in the development of their communities. Those who are widowed and isolated are more vulnerable because they typically do not own property (Witheridge & Antonowicz (2014 & Population Council 2011) Child marriage therefore hampers efforts to eradicate poverty and achieve sustainable global development. The purpose and objective of this study is to examine the effects/implication of early marriage on girls' socioeconomic wellbeing in Cameroon which is fundamental if Cameroon wants to eradicate child marriage in all its ramifications in concordance to the recommendation of the SDGs.

Methods

This contribution is based on a documentary analysis of international and national policies to which Cameroon is a signatory and desktop review of key factors involved in the socio-economic well-being of the girl-child through the seven SDGs used. The presentation of this research is descriptive and qualitative in approach using limited ethnographic work. The research employed primary and secondary data from articles, books, international conventions, decisions, documents, reports etc.

Findings: A Desktop Review of Literature

Why Child Marriage is a Concern for Agenda 2030

Currently 650 million women and girls were married as children, indicating that unless efforts are accelerated 150 million more girls will be married by 2030 (Girls not brides 2020; Plan International 2019). It is imperative to address the root causes of child marriage, gender inequality, poverty, insecurity, and the lack of economic and social opportunities for girls. Evidence shows that ending child marriage will catalyse efforts toward achieving SDGs by improving educational attainment, income, and maternal and child health.

Child marriage perpetuates poverty, inequality and insecurity and is a violation of girls' human rights to dignity, welfare and equal access to vital opportunities and services, given that, girls are deprived of their childhood and the option of education and find themselves in adult roles, including forced sex and pressure to bear children early. Hence, they are more likely to experience domestic violence, unhappy conjugal relationships throughout their life cycle. For example, in parts of North India, parents' expectation that the birth of a girl will carry lower social status and high expenditures due to dowry payments at marriage facilitates preference for boy as opposed to girl children often leading to unfavourable birth ratios. Less investment in daughters propagates under-investments in their nutrition and education which perpetuates their dependence on men and their low status (Population Council 2011). Failure to prevent and deal with child marriage will undermine the achievement of a majority of the sustainable development goals (SDG) unless concerted action is taken. Seven of the 17 SDGs used in this paper are analysed below vis-à-vis child marriage.

Efforts to Implement the Sustainable Development Goals in Cameroon vis-à-vis Relationship between the Seven Selected SDGs and Child Marriage

No. SDG	Objective	Relation to Child Marriage
SDG 1	Eradicate Poverty	According to Onyisi (2018), child marriage is linked to higher household poverty and perpetuates poverty across generations. Often linked to poverty and low levels of economic development. When girls have the skills and opportunities to secure a job and develop their skills they can support themselves and their families and break intergenerational cycles of poverty. The Fourth Cameroonian Survey Households (ECAM4) carried out in 2014, set the monetary poverty line at 738 FCFA per day as mentioned by the UN daily revenue of 1.5 dollars. 37.7% women and 37.2 men live with less than 738 FCFA per day. The poor people cluster around the rural area (56.8%) than the urban areas (8.9%) (Yute 2019:14). Choosing when and who to marry is an important decision the Cameroon government must encourage in eradicating child marriage for girls to dictate their own destinies.
SDG 3	Good health and wellbeing	Action to prevent child marriage and improving married and unmarried adolescent girls' access to sexual and reproductive health services dramatically improve health and development outcomes for millions of girls and children worldwide. This will foster positive outcomes for girls by delaying marriage and motherhood to reduce related high rates of infant mortality. Despite some efforts made by the government and its partners, the ratios of infant mortality and neonatal mortality still persist.
SDG 4	Inclusive and equitable quality Education	Quality education, difficulties in taking proper care of children's nutrition and health. Education is the one of the powerful tools available to prevent child marriage and promote gender equality. It provides protection for girls and also provides them with the knowledge and skills to determine their future.

Table 1: SDGs Versus Child Marriage

		The primary completion rate lies at 72.8% for girls and 79.7 for boys in Cameroon (Yute 2019), Girls' completion
		rate may be improved if child marriage is eradicated.
SDG 5	Gender Equality and	Addressing child marriage can be an entry point to
	Empowerment for all	addressing broader gender inequality. By tackling harmful
	Women and girls	practices and entrenched unequal social norms, we can
		work towards making sure the voices and decisions of girls
		and women are as valued as those of boys and men.
		Early and child marriage though a hindrance to education
		is still prevalent in Cameroon given that, 10.2% of women
		aged 20-24 were married before the age of 15 years and
		31% before the age of 18. Nearly 3 out of 5 women
		(59.4%) aged 20-24, with no education were married
		before the age of 18 (Yute 2019:14).
SDG 8	Economic growth	By ending child marriage and ensuring that adolescent
		nave access to education, information and services they
		children to have, and increase their educational
		attainment. This would result in increases in productivity
		and enable countries to make significant advances to
		alleviate poverty and benefit from economic growth. To
		meet the UN's SDGs, it is important to note that sustained,
		shared and sustainable economic growth is a prerequisite
		for prosperity.
		Cameroon has made strides towards the implementation
		of this SDG through the Growth and Employment Strategy
		Paper (GESP) since 2010 by implementing the MDG's
		objectives in the 2010-2020 GESP aimed at driving
		economic growth to an annual average of 5.5%, by cutting
		underemployment from 75.8% to 50% with the creation of
		rate from 30.0 to 28.7% (Yuto 2010:14)
SDG	Reducing inequalities	Reducing inequalities means not leaving anyone behind
10		no matter where they are and how hard they are to reach
10		The objective of this SDG is to gradually and sustainably
		grow the income of the poorest 40% of the population,
		empower all people and promote their social, economic
		and political integration, regardless of their profile (Yute
		2019:14). Of course, this cannot be achieved if child
		marriage is increasing. Child marriage widens wealth,
		income, and gender inequalities as well as inequalities
		between the Global North and the Global South

		considering that child marriage strives more in the Global
		South (Onyisi 2018).
SDG	Peace, Justice, and	Child marriage is a form of violence against women and
16	strong institutions	girls. Girls who marry as children are at risk of sexual,
		physical, and psychological violence from their partners or
		their partners' families throughout their lifetime. In cases
		where there is wider age difference between girls and their
		husbands, the girls are more likely to experience intimate
		partner violence than otherwise due to the intersection of
		power imbalances by gender and age (Onyisi 2018).

Source: Linonge-Fontebo, 2022.

Socio-cultural, religion and customary laws in Cameroon perpetuate child marriage, thereby compromising the development of girls and reinforce the gendered nature of poverty. Indicating that boys are also affected by child marriage but the impact is severe on girls, compounded by the gender differentiation of age to marry in Cameroon Civil Status Registration Ordinance (CSRO) (15 for girls and 18 for boys) in abrogation of Article 6 (b) of the Protocol to the African Charter on Human and People's Rights of Women, which states a minimum age of marriage at 18 for both boys and girls. Child marriage is predominant among the Muslims in the Northern part of Cameroon, where young girls are still sent into marriages with traditional rulers, lamibes, who may have ten or fifteen wives and common among the Bacheve, Oliti and Assumbo clans in Akwaya where girls at five, unknowingly are faced with the reality at about the age of ten when their supposed suitors come for them (Linonge-Fontebo, 2018).

The appropriate age at marriage facilitates maturity in overcoming problems that will arise in the future and guarantee the rights of the child to welfare, protection, maintenance, and care until adulthood. As mentioned above child marriage for women is endorsed by the Cameroon CSRO when it allows girls to marry at the age of 15 rather than the international minimum age of 18 in defiance of laws it has ratified including the CRC, CEDAW etc. Child marriage negatively affects girls more likely to marry as children than boys. Given that, early and forced marriages hamper education, psychological wellbeing, health because the child has the right to education needed for personal development, preparation for adults and effective contributions to the welfare of the family and society in the future (Judiasih et al. 2019). Child marriage endangers the health of young women and reproductive health, and it is a violation of children's rights and has a negative impact on physical growth, health, mental and emotional development and educational opportunities, a problem faced almost all over the world. The United Nations (UN) addresses and overcome child marriage by working tirelessly with member countries to implement the SDGs related to it.

Agenda 2030 for Sustainable Development (SD) was adopted at the UN General Assembly Summit on 25-27 September 2015 and became effective on the 1 January 2016. This agenda centres on 17 sustainable development goals with 169 targets, and a universal call for action to end poverty, protect the planet and ensure prosperity for all. The SDGs are one of the processes

for achieving SD that will be applied to each country that agrees to implement it. SDGs builds on the MDGs, which began global efforts in 2000 and hope to complete what was not achieved under the MDGs set targets in the set time frame of 15 years (Onyisi 2018).

The UNs 5th objective talks of "achieving gender equality and empowering women and girls". This objective states that gender equality is not only a fundamental human right but also an effort to achieve world peace and prosperity. This coincides with the third target addressing the elimination of all dangerous practices, such as child marriage, forced marriage and female circumcision". However, the Cameroon CSRO allows the marriage of girls under the age of 15 if for "serious reasons a waiver has been granted by the president of the republic." This is in disregard of international and regional commitments Cameroon says it is part and parcel of the constitution.

If Cameroon must address and reduce gender inequalities and injustice there is a need to enact the draft Child Protection Code and Family Planning Code, which stipulate the age of marriage for girls at 18 years old and establishes other protections for women and girls.

The Ministry of Women's Empowerment and the Family which is the main national women's machinery in the country focuses mostly on women in urban and semi-urban towns, where they have offices, and disregard rural women, who form the bulk of women with limited financial means. It is necessary to improve awareness and accountability so that laws are understood at the local level and accompanied by meaningful rural programs to ensure that rural women are not left behind.

Cameroon has made strides toward gender equality and the empowerment of women through major international commitments – Convention on the Elimination of all forms of Discrimination Against Women (CEDAW), that states that, the betrothal and marriage of a child shall have no legal effect and all necessary action, including legislation shall be taken to specify a minimum age for marriage (CEDAW 1981). The Beijing Declaration and Platform for Action (1995), the Declaration of Heads of States and Government of the African Union on equality between women and men, and the sustainable development goals. However, though these international regional commitments take precedence over Cameroon's national laws, customs, and traditions, the preference for customary laws remains, and means that discrimination against women continues in Cameroon, especially in rural areas. Moreover, the preamble of the constitution of Cameroon includes several provisions that enshrine gender equality. But many questions about inequalities faced by women continue to linger, such as the continuation of child marriage.

Research Implications

Causes of Early Marriage in Cameroon and in Africa

If the seven SDGs in this study have to be eliminated before 2030, there is a need to understand the causes and the effects of child marriage on girls' socioeconomic wellbeing and propose solutions on how to overcome it. The following are some of the reasons for child marriage:

1. Conflicts, Disasters, and emergencies

Food insecurity sometimes results to hasty marriages arranged by parents for girls to marry against their will. Emergencies and disasters increase economic pressure on families which escalate to early and forced marriages. Floods in the Northern parts of Cameroon, droughts and disagreements in Afghanistan have forced farmers to arrange and receive money for early matrimony of their daughters (Adamec in Ganira et al. 2015).

2. Poverty

According to Ganira et al. (2015) girls from needy households are more likely to be victims of early marriages. Poverty alongside the traditional practice of son preference influences parents to take sons to school rather than daughters in circumstances of economic constraints. High level of poverty in a community may compromise young girl's education. Economic factors are responsible for underage marriage in Indonesia (Judiasih et al. 2019). Families sometimes feel that releasing a woman to marry, reduces the burden of responsibility of the male family or the husband who marries him. Young marriage sometimes may be a bridge of social change for women.

3. Gender Inequality

Women and girls assume lower societal status emanating from cultural and traditional beliefs. Such beliefs suppress girls' capability to participate in equal roles in society. Once women and girls are denied access to education, they develop into uneducated adults with inadequate tools and resources for future generation of educated women (Ganira et al. 2015).

4. Weak legislatures

While nations have legalised right to marriage, including minimum age and consent, these laws may be applied and few prosecutions brought against law breakers. Consequently, marriage is not considered directly in the rights of the child. Practitioners regard other rights (e.g. health, education, life, development and survival) or CRC general principles such as interests of the child.

5. Traditional and Religious practices

Cultural practices among the Luos have led to boys and girls being married of at a tender age in areas where people still follow traditional rules and regulations. The Luos also believe that a girl who has reached puberty and dies before she is married and is not deflowered will remain a malevolent ghost, causing barrenness to all of her female kinsfolk. It is said that the dead will return to reproach the living unmarried girls in visions and in dreams and ask them "why did our father and our brothers allow me to go into the grave without tasting the joy of man?" (Ogutu in Ganira; Inda; Odundo; Akondo; & Ngaruiya 2015:75).

Cultural factors of people's minds that are not open or who believe in old myths that if a girl is not married in a certain period or age she will not sell well or will not have a mate and not marry in the future. The myth of not getting married when you reject the first application from a male is also a factor parents are afraid to reject applications without considering the child's age. Such believe systems are an obstacle to the elimination of early marriage especially in rural areas.

Furthermore, it avoids adultery, besides being a recommendation from religion, parents encourage their children to get married instead of dating.

6. Parenting factor

Lack of advice given to children regarding the dangers of getting married at a young age and life in undergoing a household with a relatively young age and the dominant role of parents in determining the marriage of girls, considering the assumption that children belong so that children especially girls must be obedient to their parents (Astuty in Judiasih et al. 2019).

7. Education

The education of the person who carried out the early marriage. The higher the level of education of a person, of course the higher the desire to work, career, and reach the aspirations of that person. Moreover, someone who is educating must also want to complete his education first.

8. Pregnancy outside of marriage

Due to promiscuity of relationships and the ways of dating teenagers and having a relationship between husband and wife outside of marriage forces marriage to occur without looking at someone's marriage age. The family encourages marriage to take place in such circumstances without thinking.

9. Emotional and environmental factors

Couples being carried away without thinking about mental, economic, and future readiness make a person want to get married which also influence the consequences of divorce carried out by early age couples. Also, a teenager tends to follow the surrounding social environment – following peers or associates who carry out early marriage.

From the above it is evident that the causes of child marriage are complex and systematic, ranging from inequality and poverty to customary practices and the practice is a form of violence and a development challenge that robs 14 million girls under the age 18 each year and by 2020, it was estimated that 142 million girls will be married by their 18th birthday if current trends continue (UNICEF 2012). This frustrates the future of girls and holds them and their countries back from achieving their potential.

Sustainable development cannot be achieved without gender equality (Pathania in Judiasih 2019). Gender differences give birth to the manifestations of injustice. Gender inequality does not only exists because of traditions and beliefs held by the community but due to the systems and rules that are applied to result in the planting of an understanding of the community that the position of women is lower than that of men and existence of policies that harm women (Judiasih et al. 2019). The Civil Status Registration Ordinance (CSRO), Article 52 of Order No. 81-02 of 29 June 1981 in Cameroon states that, "No marriage may take pace if the girl is younger than 15 or the boy younger than 18, unless the president of the Republic grants an exemption for a serious reason...." This legislation regarding the minimum age for marriage harbours elements of gender differences, inequalities and injustice between men and women, when the marriage law stipulates 18 years for boys and 15 years for girls. There is no reason strong enough to warrant the president's endorsement of child marriage for girls and not for boys. The minimum age for marriage in Cameroon contradicts section 356 of the Cameroon Penal Code that criminalises forced marriage. In fact, there is need for the harmonisation of these laws unless Cameroon does not view child marriage as forced marriage.

The Socioeconomic Effects/Implications of Child Marriage

Child brides end up with a high rate of illiteracy because the time they would have been using to go to school is spent at home as housewife. Child marriage is associated with lower education and economic status of girls. Child brides are less able than older or unmarried girls to access schooling and income generating opportunities or benefit from education or economic development programmes. Girls already in school are often forced to terminate their education when they marry early. Therefore child marriage excludes or prevents further education of girls and reinforces poverty. Limited mobility, household responsibilities, pregnancy, raising children and other social restrictions for married girls prevent them from taking advantage of education or work opportunities. Education is widely credited as the most significant factor for delaying girls' age of marriage.

Child/early marriage has serious health, economic and social implications for young brides, for the well-being of the family, and for society as a whole. It poses many dangers to young girls' health, which includes complications during early pregnancy and multiple births, which can lead to reproductive health risks, especially obstetric fistula and infant and maternal death. Child brides are susceptible to suffer from anaemia than adults, which greatly increases the risk and complications linked to pregnancy and eclampsia than women who wait until the age of 20 to bear children (Mathur, Greene & Malhotra 2003). Most babies of mothers younger than 18 tend to be premature and have low body weight, and such babies are likely to die in the first year of life. Obstetric fistula is among the worst of the neonatal health outcomes. Most often girls suffering from fistulas are abandoned by their husbands and become social outcasts from their communities. Complications from pregnancy can affect social wellbeing, for example, leading limited autonomy and decision-making ability and reduced opportunities to develop psychological and social skills necessary to make strategic decisions and life choices in young brides.

Child marriage also exacerbate the spread of HIV/AIDS and STDs from older husbands and lead to unwanted pregnancies, premature births, and other pregnancy – related complications which may result to death. Spousal age difference reinforce the powerlessness of the girl, because older husbands of child brides are sexually experienced, and having had more sexual partners in their lifetime increases the chances that they maybe HIV positive. The age difference between the child bride and her spouse is further compounded by power imbalance between women and men and makes open communication about sexual relations; including condom use difficult (Linonge-Fontebo 2018).

Another implication of child marriage is that it robs girls of their childhood-time necessary to develop physically, emotionally, and psychologically. Early/child marriage inflicts great emotional stress, as the young woman is removed from her parents' home to that of her husband and inlaws (LUKMEF 2015). The girl has to put up with a man many years older than her, and has to develop an intimate emotional and physical relationship with a man she has nothing in common with. Child brides have to perform heavy domestic chores, being under pressure to demonstrate fertility and responsible for raising children while being children themselves.

Limitations

The insecurity in the South West (Ambazonian crisis) and Northern (Boko Haram) Regions of Cameroon were child marriage prevails was major difficulty in collecting primary data. The data was essentially documentary and exploratory that warrants that the need to describe and explain the real life experiences of women and girls. The information is principally based on qualitative analogy. A more detailed investigation with qualitative and quantitative information will definitely give more insights into what is largely a reflection that is meant to inform action.

Originality and Value of the Paper

African Union member states committed to the 2030 Agenda for sustainable development relevant to promoting gender equality, women and girls human rights and specifically ending child marriage. SDGs are relevant to the achievement of gender equality and the empowerment of women and girls, and recognition and valuing of women's contributions are critical to achieving this goal and other related target and indicators. A conducive environment that removes barriers faced by girls must be created.

Agenda 2030 emphasises that SDGs are interrelated and ensures the integration across all 17 objectives is essential to achieving sustainable development. Secondly, each SDG can be characterised as objectives that are primarily linked to either the economic, environmental, or social system.

The well-being of the girl-child stands out as one of the twelve critical areas examined by The Beijing Declaration, to which public policies have benefitted women in Cameroon. The SDGs are welcomed in Cameroon through the National Development Plan and the scope to be an emerging nation in 2035. To transform Cameroon into an emerging nation by 2035 warrants poverty

reduction, consolidation of the democratic process and national unity in keeping with the diversity of the country linked to the SDGs. Despite efforts made by the government through the National Action Plan, Ministries of Women's Empowerment and the Family, Social Affairs and NGOs/CSOs in Cameroon towards addressing child marriage, a lot needs to be done to translate international commitments and financing to contract realisation of Agenda 2030.

All the causes of child/early marriage, for instance socialisation has to be addressed in order to reduce child marriage. From a feminist perspective, the sexual victimisation of girls is a function of male socialisation because so many young males learn how to be aggressive and exploitative of women. This exploitation of young girls by older men triggers delinquent behaviour such as running away from home and prostitution, among girls who are victims of men's aggression (Judiasih et al.2019:61). There is therefore need for concerted efforts from traditional rulers, religious leaders, NGOs, CSOs, researchers and communities to fight child marriage.

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The Relationship Between MSMEs and Poverty Eradication in Makindye Division Kampala, Uganda

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Abstract

The UN Sustainable Development Goals (SDGs) list "poverty" and "entrepreneurship" as two of its seventeen many components. This paper delves into the relationship between MSMEs and poverty eradication, looking at a case study of Makidye Division. The objective of this research was to enlighten the patterns of poverty in Makindye Division, the characteristics of MSMEs in the region, research limitations, and possible steps to eradicate poverty in Uganda by 2030. In addition, the paper uses data and literature from Uganda Bureau of Statistics (UBOS) and the Ministry of Trade Industry and Cooperatives. The finding of the study revealed that majority of the MSMEs are operated by youths between 18-30 years and were mostly women. It was also revealed that majority of the business owners have a low level of education as well as half the MSME were registered as sole proprietorships. The findings also revealed that the onset of Covid-19 affected the performance of most of the MSME and many had to either close or cut down the number of employees. Finally, the paper recommended that there should be support of market certainty for MSMEs products, particularly for MSEs to sustain the production cycle through digitalization; business owners be equipped to have the right mindset towards business; there should be formation of business incubator programs to help upcoming businesses to start right and avoid mistakes made by the already existing MSMEs; and have promotion mechanism for inter-institutional collaboration among MSMEs.

Keywords: MSMEs and Poverty Eradication, Alleviation in Makindye Division Kampala Uganda, Capacity Building, Youth, Men and Women Mindset, Entrepreneurship, Skilling and Technology, Seed Capital, Value Addition, Mentorship for Economic Growth, Sustainable Employment

Acronyms

SDGs	. The Sustainable Development Goals
MSMEs	Micro, Small, and Medium Enterprises
MSEs	. Medium Sized Enterprises
SMEs	. Small Sized Enterprises
GDP	Gross Domestic Product

IMF	International Monetary Fund
SED	Small Business Development
UBOS	Uganda Bureau of Statistics
PDM	. Parish Development Model
ACF	Agricultural Credit Facility
UGGDS	Uganda Green Growth Development Strategy
NFIS	. National Financial Inclusion Strategy

Introduction

Availability of work is a critical part of the solution to poverty. People are able to provide for themselves (e.g., food) and earn the money they need to purchase products and services through work. Wealth is also created via labour, which enables governments to provide services like as health care, clean water, and education to the poor through taxation (International Monetary Fund, 2000). However, it is not easy to get sustainable employment. Economic, social, and political activities all work together to create it. "Working out of poverty" is a good starting point, but it does not give specific advice on how to get out of poverty.

Many impoverished people's idea of employment is running their own micro or small business or working for someone else who does. As solo proprietors, managers, and employees, the poor are frequently joined in their work by members of their families as well as temporary and permanent employees. In many situations, impoverished individuals choose this type of job because they have few other options. Either suitable paid employment is unavailable or the work they undertake on the family farm is insufficient to meet their family's requirements. By working for themselves, they want to get out of poverty. The goal of small business development (SED) is to create an atmosphere where owners and employees may operate more effectively, safely, and efficiently. They can lessen their plight as a result of this. This is the difficulty of reducing poverty through the creation of small businesses.

MSMEs help bring people out of poverty by creating jobs. 783 million people, or 11 percent of the world's population, were in severe poverty in 2013, according to a new worldwide estimate. 5 The vast majority of the poor in emerging nations are either unemployed or underpaid (Sobir, 2020). It has been shown that private sector job development has been a key factor in reducing poverty. During the past 30 years, the private enterprise has helped to reduce the percentage of people living in poverty from 52% to 22% in the developing world. 6 Small and medium-sized businesses (MSMEs) play an important role in the private sector's effort to create jobs. MSMEs accounted for 90 percent of all new jobs in developing economies, creating four out of every five new posts in the formal sector (Sobir, 2020).

According to TNS, et al., (2015), as many as 10 different industrial sectors make up at least five percent of Uganda's MSMEs, making the country one of the most diversified in the world. More than a third of micro and small enterprises (MSMEs) are employed in agriculture, followed by education and health care 13%), and recreation & personal (10%).

The bulk of MSMEs in Uganda (69 percent) are under 10 years old, making them relatively new businesses. Nearly nine out of 10 Ugandan MSME owners began their businesses with their own money, and three-quarters of them are sole proprietorships. There are less than a third (31 percent) of micro-enterprises that employ a manager to oversee day-to-day operations. Over half of the owners have a secondary or higher degree (TNS, et al., 2015).

Additionally, it's a close-knit community, with 81.1 percent of MSMEs' major clientele being individuals rather than corporations, and 66% of MSMEs being located in the same general vicinity as their clients. One member of the regular five-person crew is a family member. More than half of MSMEs (63 percent) report that word-of-mouth is their primary method of obtaining suppliers and that friends and family are more likely than official lenders to have contributed start-up capital for their businesses. 73.9 percent of MSMEs learn about new business prospects through talking to consumers, yet only 15 percent of MSMEs are members of business groups, maybe because they are too small (TNS, et al., 2015).

Purpose

The UN Sustainable Development Goals (SDGs) list "poverty" and "entrepreneurship" as two of its seventeen many components. There are several ways to alleviate poverty, and one of them is business. Entrepreneurs make investments and hire employees who contribute to the company's growth, as highlighted in the aforementioned study on entrepreneurship. The creation of new jobs and the development of new skills and experience for a significant number of young people entering the labor force are all made possible by thriving businesses. The drive of this study was to analyze the level of poverty in Makindye Division, the characteristics of MSMEs, and find ways to reduce unemployment as one of the measures to reduce poverty amongst the youth, women, and men in the region. In Uganda, the Agricultural Sector is the most important and dominant sector; it employs approximately 72% of the population and contributes about 32% to the GDP. The agribusiness era is characterized by a shift from family farms to strategically placed commercial and processing units linked to modern retailers and exporters (Uganda Investment Authority, 2021).

The purpose of this paper is to determine and offer detailed findings and suggestions on how possible the SDG1 is. No Poverty can be realized through the implementation of various projects, not only in Makindye Division but also in Uganda at large. This research, therefore, focused on examining the status of Micro, Small, and Medium Enterprises dealing in value addition, their potential to grow, develop when provided with knowledge, better skills, and technology, their ability to employ more youths, men, and women in Makindye division, not only as a way of reducing poverty but cubbing on other vices that arise as a result of unemployment.

Background Literature

Poverty is defined as the lack of basic necessities such as food and shelter, as well as those who have limited or no access to these necessities (i.e. health, education). Non-material circumstances, such as a lack of rights, instability, helplessness, and indignity, are increasingly being included in the definition of poverty. As a whole, poverty is better understood when it is seen in this context (Nursini, 2020). Additionally, it makes it more difficult to assess the performance of programs aimed at reducing poverty. Defining poverty is a challenging task, and policymakers often err on the side of describing rather than defining it.

Micro, Small and medium-sized enterprises (MSMEs) have long been acknowledged as engines of growth for a country's economy. Macroeconomic goals can be met through their creation of jobs at low investment costs, the development of entrepreneurial skills and indigenous technologies, the prevention of rural–urban migration, the efficient use of local resources, and a reduction in poverty. Since the 1940s, successive Ugandan administrations have created policies to support the growth of the MSME sector, having recognized the importance and catalytic role it plays in economic development.

It is estimated that micro-enterprises employ more people and produce more goods and services than small and medium-sized businesses do in the vast majority of developing nations, including Uganda. Micro-enterprises accounted for nearly all of Uganda's MSME units in 2020, according to the country's Uganda Bureau of Statistics (UBOS). Micro-enterprises employ 89.04 percent of the total MSME workforce and produce 37.7% of the total MSME production. Because this business does not require a lot of money or experience, it is available to everybody. Micro-business entrepreneurs in Uganda tend to be poorer than their counterparts in other countries. As a result, the poor are more likely to work in small and medium-sized businesses, rather than own them. As a result, the poor's participation in business, whether as owners or employees, is critical to the growth of the economy on a national and worldwide scale.

The achievement of future SDGs may be helped in this way as well. MSMEs empowerment initiatives in Uganda have become one of the most important ways to alleviate poverty in Uganda. These initiatives are designed to increase production capacity and human capital capabilities by providing training, capital help, and technological assistance. Over time, these initiatives are aimed at changing the status of small, medium, and big businesses from micro to medium and even larger enterprises. With these developments, new jobs with high productivity are created, as well as jobs in MSME industries, which directly touch the poor. These have the potential to enhance societal well-being on a broad scale.

The SDGs have made eradicating poverty one of its most significant objectives. It has been signed and agreed to by more than 160 nations, including Uganda, to alleviate poverty by 2030. They appear to require proper measures to assist them in achieving their aim in light of the global economic uncertainty. Nursini (2020) argues that many nations are able to endure in this unpredictable environment due of their successful micro, small and medium-sized businesses. As a result, MSMEs have emerged as a key strategy for economic growth and poverty reduction. Descriptive research by Nursini (2020) found that MSMEs have enhanced the social and economic well-being of impoverished people in East Asia by increasing their access to capital. The market and the capacity of MSMEs are two major variables assisting MSME employees in growing their earnings and reducing poverty in Nigeria, according to other qualitative research like that conducted by Asikhia (2010). The income of MSEs workers in the Ibadan Metropolis in southern Nigeria, according to Adeyemi and Lanrewaju (2014), rose to 39 percent. On the same note, a value chain approach to local economic development in Uganda is needed to ensure that all value chain players, including women and youth, smallholder farmers and other agri-MSMEs, have access to suitable services to meet their requirements. With the Parish Development Model (PDM), each level of the value chain is systematically and deliberately intervened in to guarantee that once production is ramped up, it continues to be supported by stable pricing and the availability of inexpensive capital and predictable markets (Ministry of Local Government, 2021).

A case study conducted by Andre Foods International and SME Finance Working Group (2021), indicate the efforts of various banking institutions, organizations, and government towards financing of agribusiness MSMEs in Uganda. They emphasized the need to invest more money in the agricultural sector to improve its trends thereby enticing more youths to get involved in the sector, hence quitting the rural-urban migration. It futhured narrated how financial institutions like DFCU bank Uganda, Letshego Microfinance Uganda, The START Facility, UN World Food Program, and Stanbic Bank Uganda among others have come out with different programs and approaches of addressing the inadequate capital challenge. Government introduced programs like Agricultural Credit Facility (ACF) which facilitates the provision of medium and long-term financing to projects that engage in agriculture processing with a focus on commercialization and value addition among others, such efforts have moved the Ugandan MSMEs sector a milestone.

Gap in Knowledge

Obviously, many efforts have been channeled towards poverty eradication in Uganda by the government and various organizations. However, some crucial areas have been overlooked, as shared below.

There is a gap of incubation programs, which would be useful in mentoring entrepreneurs prior to investing all their capital only to end in losses. Incubator programs aim at analyzing the individual entrepreneur, their ambitions, goals, and mindset, coupled with equipping the entrepreneur with the required skills/ acumen to not only start a business but also sustain and develop it. Such programs encourage the entrepreneurs to start business outside of their passion not just because they want to earn, this in the long run builds in them resilience to stick with the business, no matter the circumstances as they look for better ways to develop it. In addition, lack of effective management during their early stages is also a major cause of business failure for small businesses. Owners tend to manage these businesses themselves as a measure of reducing operational costs. Many Ugandans starting up MSMEs have no knowledge on how to run these ideas/businesses and therefore end up failing because of lack management skills, mentorship coupled with lack of substantial capital.

Suggestions about value addition and the need for technology were made but not detailed; further explanations of what or how is it to be done was not shade light upon. One of the major challenges faced by the agribusiness in Makindye Division is the rotting of the purchased/stored goods. This could be mitigated by carrying food value addition, which requires availability of accessible technology to the micro agribusiness owners. This would enable them to reduce losses, increase profits and produce better quality products capable of beating competition both nationally and internationally.

Methodology Used

Time series from 2000 to 2020 are used in this study, which includes both primary and secondary data. They came from the Uganda Bureau of Statistics (UBOS) and the Ministry of trade. Poverty statistics, MSME production, MSME labor and GDP are examples of secondary data. The Headcount Index, the Poverty Gap Index, and the Poverty Severity Index all serve as indices for gauging the severity of poverty. The carried out a brief survey to identify the existing MSMEs dealing in agribusiness in Makindye Division, Kampala district. These approaches enabled the research to know the past, current, and predict the future of poverty alleviation.

The sampling size was 100, medium and small enterprises, the final number of successful interviews was 52, in micro and small enterprises have between 1-15 employees.

Business Size	Successfully interviewed
Micro	40
Small	12
Total	52

They carried out a brief survey to identify the existing MSMEs dealing in agribusiness in Makindye Division, Kampala district. They used primary and secondary data both qualitative and quantitative. These approaches enabled us to know the past, current, and predict the future of poverty alleviation.

Originality/Value of the Paper

This paper is original research that has been conducted by the researchers by fulfilling all the ethical requirements. The paper contributes to the corpus of information already available on the subject is the study's main goal. Small business management and performance challenges are also addressed in the report. Entrepreneurs will benefit from this study's insights into the unique problems faced by small and medium-sized businesses, and it is anticipated that it will also provide ideas for how to address those issues. Other researchers and libraries will benefit from the findings as well. It is hoped that the findings of this study would aid in the development of management and entrepreneurial skills among Uganda's MSMEs, which will in turn serve to lower the country's poverty rate.
Findings/Discussion

An analysis was done of the data collected and results presented and evaluated. The findings of the study showed that.



Figure 1: Showing Age of Respondents

The study found out that the majority of the MSMEs are operated by youths between 18-30years with a percentage of 48.07%, followed by those in the age bracket 31-35 with 32.69% and others as illustrated in the graph above. This shows the potential that these MSMEs have to grow given the energetic and visionary human resources they have. If the right knowledge and resources are channeled into these businesses they have the capacity to not only develop but also create more jobs for other youths in Makindye Division thereby reducing unemployment and poverty in the region.

Figure 2: Showing the Gender of the Respondents

It was discovered that the majority of the MSMEs in Makindye division are operated by women as demonstrated in the graph below, hence reducing the gap of gender inequality. "Uganda's economic recovery will be faster, stronger, and more sustainable if it brings more women into the center of profitable economic activity", according to the 18th edition of the Uganda Economic Update (The World Bank, 2021). The research strongly suggests that if these women get more empowered with the business skills required to grow their businesses, gender inequality will be reduced by 2030.



Figure 3: Indicates the Respondents' Level of Education



It was disclosed that the majority of the business owners have a low level of education as showcased in the graph above, which limits the growth and development of the businesses as many can hardly do book & record keeping to track business progress. There are limited opportunities for higher education and business skills.

The majority of the businesses operate on a day-to-day basis without further goals or business direction. The study, therefore, deduces that if business management, value addition practical skilling workshops, and capacity building workshops are conducted on the local level in the communities, business owners will get the required business acumen to sustain, grow and

develop their business thereby increasing income, employment opportunities and reducing poverty.

All the respondents affirmed the need for knowledge in business management, bookkeeping, record keeping, consumer behavior, technology and value addition, cost-effective production, hygiene, time management, competition, teamwork, financial literacy among other skills.



Figure 4: Showing the Major Sources of Capital for the MSMEs

It was revealed that own savings are the major source of capital for these MSMEs, they are marginal, which limits its growth and expansion, as the savings are not enough for business growth.

The Loans being the second source of capital, come with challenges such as a limited amount to borrow due to a lack of the required collateral such as land, a house, a car among others, the high-interest rates imposed by banks, and credit institutions. The government has intervened by setting up strategies and bodies, for example, Uganda Green Growth Development Strategy (UGGDS) and National Financial Inclusion Strategy (NFIS) to reduce financial exclusion and access barriers to financial services, but it has not been so successful due to lack of awareness and the difficult process of accessing such services. These financial challenges have kept many businesses at a small-scale level without hope of expansion or improving methods of production not to mention value addition.

Primary Business Activities

It was discovered that the majority of the MSMEs use agricultural produce as their raw material as 30.75% sell raw agricultural produce, 52.83% deal in value-added agribusiness like restaurants, hotels, making snacks, and selling processed food, while 16.42% of businesses

provide services. The agricultural sector is the main employer in Makindye division. Despite its prominence, it is faced with several challenges ranging from; the use of poor and local methods of production, poor transportation of produce, poor storage facilities, and limited access to financing for agriculture based MSMEs, in addition to increased taxes and market price fluctuations, which often results into losses.

The Legal Status of the Business

Nearly two out of four MSME owners had registered their businesses as sole proprietorships. The rest were not yet registered for reasons such as lack of knowledge about the need for legal existence for a business, the fear of the long registration process, and lack of willingness to pay to pay direct taxes.

Management of Business Operations

Business owners often play a hands-on role in the management of the MSMEs daily in terms of operations management, while a few business owners hire labor to spearhead the operations of the business.

Rate of Membership in Associations

Relatively few MSMEs are part of formal networking scheming amongst themselves in the region, they operate on a basis of every man for himself, and they do not consult with each other. There is a general lack of successful businesses to benchmark or even to approach for advice. There is a need to promote a mechanism for inter-institutional collaboration in MSME development by inspiring partnerships and mentorship programs.

Market Trends

Price fluctuations were another concern that business owners need to learn to cope with since in most cases they end up making major losses leading to a reduction in income, capital, and failure of paying back loans on time. This often keeps these businesses in debt, unable to grow, and operating in a survival mode.

The Durability of Raw Materials/Commodities

Since the majority of the MSMEs use agricultural products for production, they are faced with the challenge of raw materials & commodities getting spoilt/rotten, due to a lack of technology to sustain them for longer periods in the market or do value addition by processing them into better quality products. There is, therefore, a need to empower these business operators with value addition skills and provide them with seed capital to purchase the required machines to not only reduce the loss margin but also position them for competition as they bring better quality products on the market. Examples include processing the milk into yogurt, processing banana, sweet potatoes, and Irish potatoes into crisps among other value addition strategies. As these MSMEs

are supported to grow, they will have the demand and capacity to employ more women and youths in Makindye division thereby reducing poverty and crime in the region.

Effects of the Covid-19 Control Measures on Businesses

Several MSMEs were forced to either cut off workers or close due to the prevalence of Covid-19, which required the government to implement lockdowns and other measures to curb the spread of Covid-19. Uganda experienced some of the strictest lockdown measures in the world as observed by (Hartwig and Lakemann, 2020), with many businesses being forced to close or operate under strict social distancing rules, regular curfews, and challenges in accessing markets due to higher transportation and input costs. Small businesses experienced a larger decline in business activity compared to medium and large firms (Corti and Nathan, 2020).

Research Limitations/Implications

- i. Some people were not willing to freely share information about their business; they had the "what is in there for us" attitude.
- ii. Some people felt insecure to share general information about their business.
- iii. Some of them have negative attitudes towards interviewers. Some were verbally violent to the interviewers.
- iv. Some business owners were too busy to allocate the time required to answer the questionnaires.
- v. Some business owners deemed it irrelevant to share information about their business because they thought we had no tangible solution to offer.
- vi. The fear of catching covid-19 caused many especially the elderly to deny information, on grounds that interviewers may be carriers of the virus.
- vii. Lack of enough resources such as transport fees and stationery limited interviewers from reaching out to more MSMEs.
- viii. The lack of clear communication skills by the business owners made it difficult for interviewers from getting the exact information, required for the purposes of this research. Some respondents were giving misleading information.
- ix. Researchers did not finish conducting the research in time because they had multiple responsibilities on their hands. This led to the delayed analysis and compilation of the report.

Recommendations

As a result of the findings, the policy recommendations to alleviate poverty through the use of MSMEs are as follows:

- i. There should be support of market certainty for MSMEs products, particularly for MSEs to sustain the production cycle through digitalization.
- ii. Business owners be equipped to have the right mindset towards business, business management skills, among other skills to enable them to drive their business to growth and development to enable them to forsake the hand to mouth mentality, by providing capacity building pieces of training on business management skills i.e. efficient means of production, value addition and the use of modern tools and equipment, such skills will not only improve the quality of products but also increase its competitiveness on both local and international market.
- iii. There should be formation of business incubator programs to help upcoming businesses to start right and avoid mistakes made by the already existing MSMEs.
- iv. Promote mechanism for inter-institutional collaboration in MSMEs development by inspiring partnerships and mentorship programs. This will also encourage them to form a formal networking scheme in which they can sensitize and uplift one another to success.
- v. Roll out a revolving fund to offer seed capital to MSMEs and organized groups. This will address the issue of lack of capital. It will also encourage cooperativeness among businesses owners in the region.
- vi. Businesses be enlightened and guided on the right steps to legally register their businesses. This in turn will enable such businesses to win grants and loans provided by the government under its programs and strategies, which will foster business growth and development, thereby increasing the business' ability to employ more workers hence a reduction of the jobless population.

Conclusion

In conclusion, poverty reduction has been demonstrated to be a crucial factor in the success of small and medium-sized enterprises (Small and Medium Enterprises & Medium Sized Enterprises). MSMEs can help lower the percentage of the poor, the gap between the average expenditure of the poor and the poverty line and the discrepancy in the average expenditures by the poor. It was also shown that MSEs and SMEs had differing impacts on poverty reduction when indirect effects were estimated. Labor absorption in SMEs reduced the number of poor persons and the disparity between their average expenditures and the poverty line significantly, but it did not bring average expenditures closer to the poverty line. SMEs production increased significantly. Rising Medium Sized Enterprises production has a significant effect on measures of

poverty reduction derived from workers absorbed into the system. Because of this, it may be argued that the expansion of MSME output was controlled by owners, and employees in general have yet to obtain remuneration that could alleviate their economic hardships.

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Ending Poverty and Inequality: What Matters and Why

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Abstract

In attempting to articulate the ugly nature of both inequality and poverty, we explore the realities of what life is like for the world's Have-Nots. The suffering of the "poorest of the poor" has been exacerbated by the past several years of COVID-19 and its toll in terms of illness, death, and economic challenges. Virtually all areas of the globe have faced new hardships, whether Latin America, Asia, Africa, the Mediterranean and/or Middle East, North America, Australia, and Europe. This study utilizes the process of action research to design new social enterprises, implement them, apply field work methods for collecting data, and hereby documenting the results. The focus will center on grassroots innovations to design nonprofit organizations that go beyond humanitarian relief to generate real change, deep, substantive and sustainable strategies. Two facets of this work are explored. The first area of this research is social entrepreneurship, an approach by which students and professors are activists focused on reducing human suffering in its many forms The second is that of microfinance in which tiny loans are given to poor women to enable them to rise from abject poverty. Small, Utah-based techniques have arisen in college classrooms as laboratories for social innovation. After their development as practical models, they have then been implemented in communities of the poor in dozens of countries. Their methods are explained, and results are reported and assessed which demonstrate the UNSDGs can be significantly addressed, and lives of the global poor can be ameliorated in pursuing long-term economic self-sufficiency.

Keywords: Poverty, Inequality, United Nations, Sustainable Development Goals

Introduction

The ugly specter of extreme poverty has afflicted humanity for millennia. Consequences and impacts are manifold. Specific factors include suffering from hunger, joblessness, disease, a lack of education, homelessness, civil war, and a lack of women's empowerment (CGAP, 2021). According to the World Bank (2018), almost half of the world's people try surviving on less than \$5.50 each day. Research studies have documented the implications of being poor and the subsequent issue of inequality that arises. Gaps between the Haves and Have-Nots continue to assault people's well-being (Human Security Trust Fund, 2019). The 2007-9 worldwide "Great Recession" took a heavy toll on the world economy, especially for poor countries.

More recently, of course, the 2020-2022 global "Coronavirus Pandemic" made things worse for millions more. The relevance of this paper in our present circumstances of the COVID-19 pandemic cannot be overstated as people seek to answer questions about jobs, justice and their health. Thus, we explore ways academics, students and entrepreneurs can design their business and professional impacts to survive and maybe even thrive in challenging times. What is

increasingly relevant and required these days is the ability of experts, governments, universities and nonprofits to generate capacity-building outcomes for those who struggle economically, even in large well-developed nations like America. As the U.S. and the rest of the world copes with the unprecedented disaster of the Coronavirus pandemic, worries have been expanding. In 2020, according to the Coronavirus Resource Center (2020) at Johns Hopkins University, some 17 million people globally had the virus and sadly some 667,000 had died. That number continued to mushroom leading to the 460 million cases and over 6 million deaths as of spring 2022 when numbers began to decline (Worldometers, 2022).

Among those who battle the deleterious effects of mass pandemics globally, poor families face the largest challenges. This paper spells out critical factors giving rise to what the United Nations articulates as poverty leading to disparities between rich and poor, men and women, adults and children, urban and rural (United Nation SDGs, 2015). Multiple strategies are analyzed as counters to reverse the plight of the poor, drawing on initial forays into designing interventions that address these crises (Woodworth, 2000). Tools and methodologies will be examined. They involve Utah college students, MDs, NGO donors, schoolteachers, entrepreneurs, nurses, professors, and others. Analyses of what things matter, and why they are workable, will be highlighted.

Key interventions are explored, including Utah-based NGOs I have developed with collaborators doing social entrepreneurship and village banking through microfinance, building village schools and educating poor children, installing clean water systems, launching square-foot-gardening techniques, implementing literacy programs for indigenous women, creating rural healthcare systems, establishing methods for social entrepreneurship, organizing worker-owned cooperatives, and more. Combined, they have generated a useful framework for expanding the quality of life in developing nations (USAID, 2020; Yunus, 2009). Over the decades we have ensured that such approaches are sustainable for the long-term. Our Utah-initiated cases of NGO work in Africa, Asia and Latin America are briefly summarized, with particular attention paid to the logic of why and how they succeeded in raising hundreds of millions of dollars while empowering tens of millions of extremely impoverished families to move up the "food chain" toward greater equality and social justice.

Assessing existing NGOs and exploring potential new innovations that will further strengthen the social and economic impacts will be analyzed. These will summarize things that absolutely matter and show why they are so critical in securing capacity-building among the poorest, most ignored, powerless people on earth. Each intervention is one that was carried out in partnership with the Have Nots as critical stakeholders in the process of social change. They offer additional steps toward ensuring a better future for those who suffer from both poverty and its resulting inequality.

A Personal Context

It is often suggested that real insights about social innovation come from one's own experience. This certainly seems to be the case when one talks of trying to change the world. Thus, I will speak from my own life, my personal practice, not just abstract theories and/or the observations

of others. But I do so while realizing my many limitations and the awareness that we must all continue to learn, to question, and to critique our life's work. Hopefully, these personal illustrations will show the tremendous possibilities of generating action-based learning and research, not only for academic purposes, but for engaging professors, students, and alumni in reducing human suffering and building civil society around the globe.

The context for this paper is related to a variety of social enterprises emerging from action research courses over some 40 years (Smith and Woodworth, 2012). These began back in 1980s when a small group of students and I gathered data on poverty and unemployment in the Philippines, and then collaborated with Filipino managers, academics, and church representatives to plan and roll out a microcredit nonprofit in that country. In spite of criticisms from academic colleagues, deans and other campus administrators, our little start-up survived, growing to have some 600 employees operating a dozen offices throughout the Philippines, as well as in Ghana, Peru, Mexico, Guatemala, Nepal and El Salvador. Thus far, we have raised some \$168 million, trained over a million microentrepreneurs, and created over 300,000 new jobs through self-employed microenterprises. Developing our NGO successfully over 30 years helped me learn that we as academics can change the world, not just teach theoretical courses, do research and publish statistical data.

At the outset, we should briefly highlight a few key terms so readers will understand the concepts being addressed. Below is a short listing:

- Civil society (sectors of a country's social problems and challenges, sometimes referred to as its "social sector" or "third sector," or other terms. In contrast to the traditional arenas of the private sector, such as business and for-profit enterprises, and/or public sector systems like federal, state, regional, and city governments; schools; and so forth)
- Humanitarianism (the belief and practice of regarding lives as individuals perform benevolent treatment of and offer assistance to others in need, to improve their living conditions)
- International development (usually implies large-scale government programs focused on alleviating poverty, fostering economic expansion, and improving living conditions in poor nations around the globe)
- Microcredit (tiny loans or microloans to the very poor)
- Micro-bank (a village or communal bank group, usually of self-organized poor women)
- Microenterprise (a very small income-generating activity or family business)
- Microentrepreneur (recipient of a microloan with which one can start or expand a small business)

- MFI (microfinance institution—term and acronym used herein for all financial services for the poor)
- Microfinance institution (a more-inclusive term for the above five "micro-" terms, sometimes also including programs such as client savings, health insurance for the poor, education loans, and others)
- NGO (a nongovernmental organization or nonprofit that may provide a range of humanitarian and development services, such as literacy, healthcare, education and schools, crisis response and aid, computer skills, village progress aid, agricultural help, and women's empowerment, as well as microcredit itself)
- Social entrepreneurship (a relatively new field for studying and implementing societal innovations above and beyond the private sector of business and/or the public sector of government. Sometimes referred to as the practice of nonprofit or charitable efforts)
- Social entrepreneur (a person who seeks to design programs to improve society, using business methods, not simply charity)
- Social impact (the seeking of funding that leads to major economic results, not merely charity but also long-term innovation)

To summarize, the structure of this research is based on five core themes headlined below in sequence:

Purpose: The objective of this paper is to explicate ways Utah professors and students have successfully designed and implemented non-governmental organizations (NGOs) drawing on various UNSDGs, with an emphasis on No. 1 combating poverty, No. 10 reducing inequalities, but also addressing additional needs such as No. 4 strengthening education, No. 3 improving health and well-being, all to help find "transformative pathways in turbulent times" (United Nations, 2020, p.3).

Design/Methodology/Approach: This study consists of doing action research, the social science methodology pioneered in the 1950s by Kurt Lewin (1951) and followed up later by many others (Argyris, 1985). It's an approach to doing studies in the field by practitioners rather than from a university center. Instead of congregating statistical data in a lab or from a computer, action research is hands on. It is widely used today to initiate field experiments, assess their impacts, carry out organizational evaluations, and thereby, inform the public how we may ultimately change the world for the better. The cases examined below are practical reports and assessments of grassroots initiatives designed as models for social change that reduce human suffering. We follow them through their original conceptions, structures, funding, and implementation. Finally, this paper describes and analyzes their roll out, and subsequent impacts. While the details of our ethnographic methodologies are examined in considerable detail later in this paper, suffice it to say I recruited hundreds of students in my business school classes over several years who sought

to "change the world," as they put it. We designed new NGOs which were consistent with the SDGs of the United Nations. Training grad students, forming action teams, preparing the sequence of steps when we "hit the ground" in several developing nations, implementing microcredit and social entrepreneurial methods, all combined to generate a powerful process with significant results.

In carrying out this research, two main concepts are the main focus of inquiry: social entrepreneurship and microcredit. We introduce the main idea of each below.

Social Entrepreneurship

First, we turn to the basics of social entrepreneurship. A relatively new idea in recent years, it has arisen as a more dynamic construct than simply using terms like nonprofit, charity, and other terms. Why? Because it suggests business implications, taking action, and innovation. No less a figure than Peter Drucker (1999) argued in the Harvard Business Review that social entrepreneurship would become the second careers of masses of professional or knowledge workers. This literature has exploded since (Aldrich and Zimmer, 1986; Bornstein, 2004; Dees, 2007; Mair and Marti, 2006).

Perhaps innovative changes in business schools and the Academy of Management (AOM) described below will illustrate. Business schools and management education today are in flux. and their various conditions are in a state of dynamism as never before. These changes have led to academic institutions creating new courses and degrees in social entrepreneurship. Not just regular entrepreneurial business start-ups or traditional management emphases, but "social" entrepreneurship. Courses in social entrepreneurship abound: Harvard's Social Enterprise Program, Duke's Center for the Advancement of Social Entrepreneurship (CASE), and dozens more. They offer certificates in "Innovation and Entrepreneurship," and others have multiple courses and program emphases using terms such as the University of Pennsylvania's "Social Impact and Responsibility," or at schools which offer certificates in "Innovation and Entrepreneurship." Stanford, along with Yale, sponsor Programs on Social Enterprise (PSE). Boston College designed and rolled out its famous Center for Social Innovation (CSI) offering a variety of relevant courses. The University of Michigan runs its business school's Center for Social Impact offering a dozen relevant courses. Berkeley has courses in Entrepreneurship to Address Global Poverty, Social Sector Leadership, and more. Cornell's Social Entrepreneurship Programs include the Center for Transformative Action nonprofit incubator and a Societal Solutions Scholars Program. All told, there are hundreds of such courses.

In some instances, universities have established formal degrees, programs where graduate students may earn a Master's in Social Innovation. Schools like American University's Master of Arts in Social Enterprise, USC's "Master of Science in Social Entrepreneurship," NYU's "MBA in Social Innovation and Impact," Georgetown's "Master of International Development Policy," and Pepperdine's "MA in Social Entrepreneurship and Change."

Another exciting development in the rise and study of innovative changes in business has been the fact that the Academy of Management, the world's most prestigious academic group, as well as the largest management association for business scholarship has begun emphasizing social entrepreneurship issues. Some of its annual meetings have had themes such as "Capitalism in Question, "The Informal Economy," "Practice and Research," and "Doing Well By Doing Good." The academy's leaders articulated their visions of these annual research conferences as an opportunity to "consider whether our research and the knowledge we produce contribute to the wellbeing of the larger society in which we live and work" (AOM, 2020).

The theme of one recent year's conference attended by as many as 7,000 management scholars was "Dare to Care: Passion and Compassion in Management Practice and Research," Its goals were "to dare managers and management scholars to care more deeply about our roles – to have passion about what we do and compassion for the people for whom we do our work. "Dare to care" orients managers to a focus on enabling others to create, produce, and deliver goods and services that enhance the wellbeing of, and generate value for, all the stakeholders involved (notably customers, employees, investors, and the public). Daring to care encourages management scholars to expand their focus toward an understanding of how solving organizational problems might ensure a sustainable future" (AOM, 2010).

A number of sessions and papers at these recent AOM conferences have emphasized using business schools and research to understand and practice the values of social innovation and relevance and in our disciplines. Titles included phrases like "Navigating the Tensions in Poverty Alleviation Research: Scholarly Rigor vs. Practical Relevance;" "Base-of-the-Pyramid Interventions," "Social Capital and Social Exchange;" "Ten Years of Daring to Care: The UN Global Compact (2000-2010)—What Has Been Achieved;" "Daring to Measure Social Impact: Performance Management in the Social Sector;" "Sustainable Global Enterprise: Building Research on Caring and Daring MNEs;" and "Social Repair Through Micro-Business."

I believe these socially relevant events to be an exciting and path-breaking new agenda for management scholars and practitioners. The latest such example? AOM's 82nd conference for August 2022 has as its relevant theme: "Creating a Better World Together."

The other key concept to be explored in this study is that of microcredit. Immediately below, the paper describes and defines its meaning.

Tools of Microcredit

It seems appropriate at the outset to introduce readers to the role of microcredit and related terms such as microfinance, microlending and microenterprise and microentrepreneur. Combined, these are core strategies for empowering the poor which help create jobs and also show the poor that they matter. In part, this is because they are trained and given a microlean with which to start a tiny business, a microenterprise.

I'll never forget my early experience implementing microcredit which is illustrated by a single individual. It involves a Honduran woman with whom one of our NGOs was preparing to offer a \$100 microloan to purchase chickens and launch her business. After a few days training, we met with a group of her and her neighbors to issue these tiny loans. But she broke out in tears, telling us she didn't merit financial support. She declared she was just a "poor Indian woman," unworthy of a hundred dollars. In fact, she said she had never even seen \$100. Such is the despair of those in extreme poverty. In her case, we coached and encouraged, and she finally took the loan. She bought baby chicks and feed, and within four months had paid us back, plus interest. We then issued her a \$200 loan and the same thing occurred as her microenterprise grew. When I last visited her humble shack where she was raising her children as a single mother, her efforts had paid off amazingly. She had a sense of self-worth and dignity, and her expanded coops contained over 5,000 chickens!

This paper elucidates the growing phenomenon of microcredit—what it is, how it strengthens poor families, where it works, how it is structured, and the extent of its impacts. While many families experience the stress and strain of poverty, new solutions are being implemented to help overcome the debilitating effects of joblessness. One of the most innovative is microcredit and its related tactics to empower the poor and enable those who struggle to enjoy greater incomes, experience a sense of dignity, solidify family relationships, and improve their quality of life.

Such an approach differs from large-scale, expensive programs that broadly assert that their objective is to eliminate poverty, in general. Instead, microcredit is a sort of boutique strategy which has narrower goals. It uses a business model, not charity, to lift the poor, and it accomplishes this, one family at a time. In doing so, the poor experience a better life, feel more dignity, and are not dependent on huge government programs. The phrase I often use in my consulting and working with microenterprise organizations is that it gives the poor "a hand-up, not a handout."

To begin with, let us clarify these terms a bit more. First, a microenterprise is usually created through nongovernmental organizations (NGOs), an increasingly used expression often akin to nonprofit foundations. A microenterprise signifies one's very small business, usually operated by just one or two family members. Next is the word, microcredit, by which I mean "microlending" only, providing tiny amounts of capital loaned for income-generating projects. Microentrepreneur is the term for the recipient of microcredit, i.e., an individual who seeks a small loan with which to start or expand one's tiny business. Microfinance is a more encompassing word that may include microcredit for the microenterprise operated by the microentrepreneur. It may also include other economic services for the poor like a microentrepreneur's savings account, microloans for housing or education, microinsurance, small-scale agriculture loans for seed or tools. NGOs that provide this broader array of financial services are often described as microfinance institutions (MFIs). One may wonder where these new financial strategies came from.

Three financial experiments gave rise to this microcredit movement. One MFI that claims it was the first is ACCION International, an NGO that was doing traditional development work in Latin America during the 1970s. It began to provide simple, tiny loans for start-up economic activity in

1972 in Brazil. Seeing that a small amount of credit could help a poor family improve, the practice began to spread. While ACCION's early efforts were limited to Latin America, it eventually began to expand by launching new offices in the U.S., Africa, Europe and Asia. In recent years, ACCION has impacted millions of the global poor in 55 countries. It currently offers savings programs to microcredit clients as well as insurance, tech assistance and other services (ACCION, 2022).

Another pioneering organization was the Grameen Bank of Bangladesh, based in the capital city, Dhaka. It was the first microenterprise support organization to achieve major growth and substantial scale. Founded in 1976 by Professor Muhammad Yunus, a U.S.-trained economist, Grameen created a peer-lending structure where five to six women each received individual loans and jointly guaranteed all the loans in their group. Weekly payments were small and easy to understand, and all loans were one year in length. The groups met weekly in a designated center, meeting with five to seven other groups, to make loan and interest payments and to support each other's business success. This group structure fostered self-esteem and a culture of mutual accountability that supported high loan repayment rates, high savings rates, and low levels of business failure.

Today it has more than seven million clients, 96 percent of them women. Currently it has given out over \$20 billion to 9 million mostly female borrowers in thousands of villages, with a payback rate in excess of 99 percent (Grameen, 2022). One of the most important features of Grameen is its openness and commitment to helping other NGOs start microcredit programs. Today there are hundreds of replication efforts in many nations that were built off the Grameen model.

The third pioneering MFI, FINCA International (Foundation for International Community Assistance), did not become a major organization in the emerging microcredit field until the 1990s. But the founder, John Hatch, was a key player in the efforts to generate interest and public attention for the MFI field, beginning in 1983. Indeed, without any knowledge of the Grameen Bank in far-off Bangladesh, or of the microcredit experiments by ACCION in Latin America, Hatch invented another type of solidarity group which he called Village Banking. In his model, the loan officer would go to a village, explain the concept, and ask the village elders to choose 30-40 impoverished women who each needed a \$50 loan to start or expand a business. Later Finca staffers returned for the repayment.

FINCA's model was implemented in those early years in several Latin American locales, but more recently has expanded to Africa and the former USSR. Today it has over nearly 3 million clients who comprise some 34,000 village bank groups of mostly poor women living in 41 nations (FINCA, 2022). FINCA's strategy emphasizes financial inclusion as a core value undergirding all it does. Further details about the rise of microenterprise through ACCION, Grameen and other cases may be obtained in an early volume (Woodworth, 2000).

This microcredit strategy for empowering poor families has become perhaps the most innovative development tool to globally empower millions of poor families in the last several decades. It is impressive for several reasons: It defies the traditional assumption that solutions are best invented in industrialized nations and that top-down development is required because national political

leaders' support is essential for success. Instead, microfinance essentially turns traditional borrowing and finance for families upside down.

As microcredit has been increasingly recognized for its contribution to poverty alleviation, many government and multilateral organizations (such as USAID, the World Bank, the United Nations) have become involved. Likewise, there are important microenterprise industry research and policy organizations helping to further the impact of microcredit for the poor: They include the UN's "International Year of Microcredit," the Consultative Group to Help the Poorest (CGAP), the Small Enterprise Education and Promotion Network (SEEP), and the Microcredit Summit. With the above context, we turn to my research with local, Utah-based NGO efforts.

Action Research Findings

The results of NGO cases for this paper center on both social entrepreneurial work and microcredit strategies. The paragraphs below report on a mix of programs we developed in Utah at Brigham Young University, Utah Valley University, and other area schools of higher education to carry out several UN SDGs. They are organizational strategies carried out using either microfinance or social entrepreneurship mechanisms to improve societies globally. Below we briefly describe several cases addressing the challenges of recent years and ways we sought to ameliorate matters.

International Aid, Inc. in Developing Nations

One of the first projects to counter poverty in my courses is a current NGO which we launched some two decades ago after hurricanes wreaked havoc in Latin America. Let's refer to this nonprofit enterprise as International Aid, Inc. (IAI). It emerged from my microfinance course at a school of business in Utah.

In 1989, I had designed and began teaching an innovative college course to be applied in the Philippines using various designations: Microcredit, Microenterprise, Microfinance, and so forth. Although it started small with just a handful of students, it grew to having hundreds of interested young people register, both undergraduates and graduate students. Eventually, colleagues at other schools wanted to establish their own courses, and the idea of earning college credit through such experiences is now available through microfinance courses at over 600 colleges.

As one of our early initiatives, IAI focused on empowering those we call "Necessity Entrepreneurs" in developing nations through microfinance. IAI became an innovative example of social entrepreneurship utilizing student volunteers, local entrepreneurs, alumni, and faculty in mobilizing our collective efforts to serve the poor that we started in Latin America. Facing the question of whether or not a business school has anything of relevance to a natural disaster which devastated a huge region, we extended my course of a decade earlier for the Philippines to become a new, not-for-credit course in January 1999 called "How to Change the World." Eventually some 70-plus students signed up for the experience and formed self-organizing teams to plan how we might assist the victims of the hurricane. In spite of cynics at the

university, who claimed students could not address such major catastrophes, we prepared 46 volunteers, who each spent two months or more in Honduras that summer. About \$116,000 was raised for establishing 47 communal banks, as well as recapitalizing an additional 52 bank groups of FINCA International, our MFI partner, whose client resources had been destroyed by the flooding.

MBA students served as on-the-ground team leaders over specific projects in-country. In addition to microfinance and economic development, approximately 20,000 hours of community service was rendered by IAI volunteers: Shoveling mud out of schools, rebuilding houses, mentoring street children, teaching computer skills, and delivering babies in rural health clinics. Over 800 jobs were created by these new microenterprise start-ups, which benefited some 4,000 family members.

That first experience of helping Honduras led to increased motivation for doing similar work elsewhere in subsequent years. As students, donors, and faculty began to feel empowered in their ability to make a difference, new crises inspired new strategies. Thus, in winter semester 2000, some 88 volunteers were organized and trained to serve during the following summer of that year. We raised over \$250,000 and sent teams of young social entrepreneurs to continue our efforts in Honduras, as well as to expand to Venezuela, Peru, and El Salvador. We began to partner with more NGOs in these countries, starting more village banks in Honduras and El Salvador, as well as providing microenterprise training programs in Peru and Venezuela.

Gradually IAI enlarged the scope of its efforts by going to Brazil, Bolivia, and Uganda, as well as continued its strategies in Central America. Expanded impacts have continued to nations like Fiji, Nicaragua, Tanzania, Thailand, and India. Today it operates alone and/or with partners which are additional NGOs that offer various services to the poor, most of which fit well within the UN's SDGs: Microcredit (SDG Nos. 1 and 10), square foot gardening (No. 3), adult literacy (SDG No. 4), women's empowerment (SDG 5), home construction, agricultural and other appropriate technologies, as well as training in computer skills and English as a Second Language (ESL) (SDG No. 4), serving in rural health clinics (SDG No. 3), teaching in schools (SDG No. 4), HIV-AIDS education and prevention (SDG No. 3), fostering peace by providing refugee support for Middle Eastern families driven from their communities to camps elsewhere (No. 16), installing latrines in multiple rural villages (SDG No. 6), rebuilding schools after the 2015 earthquake in Nepal (SDG No. 4), establishing savings and loans associations in isolated areas of multiple nations where none existed (SDG No. 1), and volunteering in orphanages (SDG No. 4), and more.

International Aid, Inc. has worked to expand its donor relationships by building partnerships with a number of businesses, which range from small firms like Marketing Alley in Utah and Smog 'n Go in California, to large companies like Starbucks, Novell, the Marriott Foundation, Walmart, Unitus, and Intel. They have collectively led to huge impacts for "Necessity Entrepreneurs" among the poorest of the poor. Not only have we drawn on students from my own university over these years, but also from dozens of other schools like Stanford, Colorado State, Virginia Tech, Yale, and Washington University.

When the UN established its list of SDGs in 2015, there were some 736 million people still lived on less than \$1.90 a day. One in every ten people was extremely poor. IAI has primarily sought to help eradicate poverty, but being poor is one of the most challenging goals to overcome. This student-led MFI has made a small dent in global poverty, but it's nonetheless a dent. IAI has grown to operate in 17 nations from Fiji to Tanzania implementing programs such as social entrepreneurship, sustainable development, literacy and computer skills, microentrepreneurship training, and so forth.

For over 20 years, some 3,000 IAI student social entrepreneurs have volunteered to spend 3-4 months each laboring to empower the disenfranchised. But the world still has a long way to go.

Latino Microcredit in Utah

Another case is a small, local community-based nonprofit example implemented by college students and me establishing an NGO in 2003 using the university as an incubator to recruit, train, mentor and give \$500 microloans to Latino immigrants in our local valley of the western United States where the school is located. I'll refer to the organization as "Latino Microcredit" (LM). It began because growing numbers of Latino immigrants were moving into Utah Valley where we live. They struggled with the challenges of housing, getting sufficient food on the table, transportation, schools for their children, and employment.

We designed a four-pillar system for operating its program: Entrepreneurial training, group support, having a mentor, and receiving loans. Briefly put, training seemed to be of interest to 78 percent of Latino adults in a survey we conducted early on. So, we designed eight modules, one to be taught each week for 8 weeks. It covered topics like what microentrepreneurship is, how it works, what a loan's principal and interest are, as well as covering other relevant topics–simple accounting and bookkeeping, sales and marketing, customer service, productivity, human resources, teambuilding, business English, and so forth. In addition, it was decided that as learning grows and application occurs through the use of cases, trainers would begin to help the participants design their own microenterprise business plans.

During these weeks, would-be microentrepreneurs learned about each other, worked on training cases as a team, shared ideas and experiences. This system is one of mutual support built solidarity and trust. If group members went on to complete the eight sessions of training and qualify for \$500 loans, a graduation ceremony was held, certificates of completion were given, as well as the loans. Each member of the group signed a commitment to repay each other's loans, in addition to one's own, the group thereby acting as social collateral. This technique is sometimes referred to as "peer-lending" or "solidarity group loans." Group commitment and peer pressure served to minimize borrower default rates. Also, they taught responsibility and the importance of repayment on time and in full for the amount due.

After graduating and obtaining their first LM loans, the microentrepreneurs next turned to launching their tiny businesses, and each was assigned a volunteer mentor who agreed to coach them at least monthly throughout the next year. These mentors were older, experienced

individuals who had enjoyed considerable business success, knew how to operate within the realities of the U.S. business environment, and were fluent in Spanish language skills.

As of now, Latino Microfinance seems to be succeeding. Hundreds of would-be microentrepreneurs have received orientation and/or training. Those who completed the training have obtained loans, started microenterprises, and, so far, at least until now, nearly a hundred percent of them have paid back their microcredit debts, 97.2 percent to be precise. LM eventually shifted from being a university class project, or a short-term community effort to become a legal 501(c) 3 nonprofit so it could expand its services and loan capital to greater numbers of poor families. The hope is to eventually have the capability and resources to assist thousands of impoverished Hispanic families in the Utah Valley region so they can progress from the "underground" or "black market" economy to the point that they may qualify for larger-scale loans from regular banks in the formal U.S. economy.

This application of the SDGs in our own community has faced challenges. They included the fact that although the Provo mayor originally endorsed this project and committed a few thousand start up dollars, he later reneged upon learning LM was serving "undocumented" families from Central America. LM has also had to move its operations around for various reasons, including from the initial campus to Centro Hispano, and at other facilities. We enjoyed operating on the campus of Utah Valley University for years, working and training clients at UVU's Small Business Development Center. Being centrally located in the valley made it easier and more accessible for Latino clients to get to for training and mentoring.

As a social enterprise, Latino Microfinance fits well within the United Nations agenda of working to eliminate extreme poverty (SDG No. 1) and help reduce inequality, even in Utah (SDG No. 10). To do so means we must labor to reduce and eventually eliminate terrible poverty within one of the world's wealthiest nations. LM's growing stronger today with financing from banks and credit unions, has convinced me that through this small experiment we can generate changemakers locally, as well as reduce poverty among minority populations which are especially vulnerable, doing so in our home communities as well as globally.

Microfinance Accelerator

A final case of this research, and the largest MFI of all this author has established, is the launching of an NGO we will refer to as the "Microfinance Accelerator" or (MA), an effort we established beginning in 1999-2000. It became a major microfinance institution (MFI) which I co-founded and served as the first board chair—along with some entrepreneurial friends of mine, showing how like-minded business executives can come together, collaborate with amazing young people by hiring a few students, and sharing how their best practices can be integrated in assisting small MFIs around the world to rapidly scale up with our financial backing. Although well-established before the UN's SDGs were conceived and articulated, the first UN goal of eliminating poverty was the central mission of MA.

We learned how to be laser-focused, bring together a mix of management competencies with young students' energies, and become a major player around the world in scaling up the global field of microfinance. MA board members brought not only business savvy to the organization, but they were all socially conscious executives. One had been the marketing head at Apple, Inc overseeing the launch of the MacIntosh Computer in Silicon Valley. Another was the head of Bain Capital in Boston with \$150 billion in investor assets being managed today. Others had extensive experience as advisors to Bill Gates at Microsoft, founders of tech companies, and more. All were social entrepreneurs seeking to better the world. For over 15 years, we garnered loan capital for some 20 MFIs which totaled over \$1.2 billion in loans and investments in Africa, Latin America, and Asia. With the financing we did, these once small MFIs rapidly ramped up from their early years when they had a total of less than 300,000 clients, today they have an astounding 40 million borrowers.

Soon after beginning, in 2002, MA established its own little MFI in Mexico in an indigenous region in the state of Hidalgo, to experiment with assisting tiny business start-ups. That practical fieldwork gave the team the ability to learn quickly what was successful and how to design and launch a new organization in Latin America. The board reached out to partner with a Peruvian NGO which was beginning to expand throughout the region of Latin America. Efforts began to lease facilities, hire and train a small Mexican staff, and then begin offering training in practices of microlending, savings, and budgeting one's income. Starting from scratch in January 2002, the first loans were issued in April and by December the Tula MFI had grown to serve some 2,500 clients. Astoundingly, the new social business enjoyed 100 percent of expected repayments, along with interest rates and a 99 percent client retention rate. The average loan size for clients was a mere \$95. The organization grew to a total of 10,401 clients within several more years. Altogether, MA has invested some \$1.9 million in our first Mexico project. The beginnings of MA's outreach in Tula alone have grown to serve more than 26,000 women clients.

From that humble beginning Microfinance Accelerator expanded with ever-larger donations from individuals as well as large family foundations, often drawing on relationships between board members and their professional colleagues. Thanks to some members' personal wealth, several million dollars was obtained. Then, with that success, even larger contributions came from our friends, including \$3 million from the Bill Gates Foundation early on; several million dollars more from Pierre Omidyar, founder of eBay; and from Apple founder Steve Job's family foundation. The Omidyar Network, for example, gave MA several one-to-two-million-dollar grants early on. In 2008, it contributed \$9 million to be used over the next three years. It was clear that if Microfinance Accelerator developed a businesslike model for expanding microcredit, considerable potential lay in securing the necessary capital for reaching huge success as a "partner to the poor." It would also be consistent and support the soon-to-be-established United Nation's SDG No. I in attacking poverty, as well as other priorities such as SDG No. 8 by building systems for more and decent work and economic growth, No. 9 to strengthen industry that would thereby foster innovation and better infrastructure, and No. 10 which sought to reduce inequalities.

Over time, a new potential MA partner was identified in India, called SKS Microfinance (Swayam Krishi Sangam), a small MFI located in the state of Andhra Pradesh. It appeared to be a good

model with a creative approach that was perceived to have high growth potential. Yet it only had some 5,000 clients, despite seeming to have much promise, because it was well run, was efficient, had good technical systems, and other qualities. Without more funding, however, it could only serve several thousand microentrepreneurs in a nation of more than a billion individuals, because it lacked sufficient capital. Instead of a promising future, its limitations were clear.

Small grants of \$100,000 from Microfinance Acceleration began to spur major new growth at SKS. This became a genuine win-win arrangement for the poor of India, their local MFIs, and MA itself. The initial MA support to scale up SKS also led to significant internal growth. By 2010, it had engaged with 6.8 million impoverished Indian borrowers and held \$624 million worth of microloans (Strom and Bajaj, 2010). Eventually, after tripling its capital and client base further, and for multiple growth reasons, SKS rebranded itself with a new name—Bharat Financial Inclusion Ltd.—and added new services.

Beyond SKS, MA began to establish partnerships with other small MFIs that were well run, yet lacked capital for significant client growth. They included Finsol in Brazil, Credex in Mexico, LifeBank Foundation in The Philippines, Fondo de Inversion Social (FIS) in Argentina, and Bandhan in Kolkatta, India. In addition to these and other MFIs, Microfinance Accelerator pursued a number of other prospects and began funded for their growth. Over 15 years, we garnered loan capital for some 20 MFIs which totaled over \$1.2 billion in loans and investments in Africa, Latin America, and Asia. With the financing we did, these once small MFIs rapidly ramped up from their early years when they had a total of less than 300,000 clients, today they have impacted an astounding 28 million borrowers.

The organization enjoyed considerable recognition and generated important results, so much so that it eventually split off into several divisions or branches which continue to this day, fully consistent with the UN's SDGs.

Limitations of this Research and its Implications

Clearly there are aspects of this paper which are limited, both for scholars and managers working on the United Nations' Sustainable Development Goals throughout the earth. My research is practitioner-based and grows from the action research I've done over several decades. So, it's not a study using statistical information, number-crunching methods, and/or other approaches reported in academic journals using statistics and data sets. Instead, this research is qualitative, on-the-ground learning. It consists of social applications, applied economics, and sociological cases analysis. Hopefully, some academic readers will be interested in further research of the concepts and cases above, thus, enlightening the world about microcredit and social entrepreneurship.

However, this study also suggests ways that the average person, having little money or lacking a PhD has the capacity to improve society. In some respects, one might see that they, themselves, can remake the world. Drawing on the words of the great anthropologist, Margaret Mead (2022),

the following is suggested: "Never doubt that a small group of thoughtful, committed citizens can change the world; indeed, it's the only thing that ever has."

The Originality and Value of this Research

This paper offers further value-added dimensions to the notion that while the world's impoverished masses struggle continuously, each human being can labor to reduce suffering, empower the poor, and work for a more peaceful and just society. Through the concepts and cases above, it can be surmised that the power is within us to conceive new ideas, design frameworks for thinking and action, such that life becomes more bearable for others. Instead of simply depending on large institutions like the U.S. federal government, big banks, the United Nations, major churches, World Bank and other top-down structures, we can invert society and work from the bottom-up. In so doing, we are able to strengthen civil society and raise the level of well-being for the masses.

The essence of my argument specifically is that college students, along with faculty, can become radical social innovators by inventing new courses and projects using entrepreneurship and microcredit to empower the world's poor with sustainable strategies that last. In several instances, the spin-offs from my courses have led to collaboration and involvement with students from other universities that joined our on-the-ground summers of volunteering in the field. They include students from Portland State University, the University of Utah, Stanford, VA Tech, Utah Valley University, Colorado State, University of Washington, UNC, Harvard, and Berkeley, as well as Brigham Young University. In my view, both individually and collectively, people can truly make a difference in society. All it takes is blood, sweat and tears.

Conclusions

Finally, as we have explored the relevant United Nation's Sustainable Development Goals and their applications today, we see applicable results. This paper suggests two things: First, at the macrolevel, we see that the UN's SDGs have generated important values and future objectives for the masses of people on our earth and we can all facilitate this movement. Second, these goals are relevant in inspiring the next generation of young people across the world to mobilize and make a difference. Not just from the "Big Boys," the massive institutions like the World Bank, USAID, or the UN itself. But other movements from below, carrying out small, grassroots microstrategies that can also play a role in development.

In so doing, let us remember the philosophy of the great South African leader, Nelson Mandela (2022): "As long as poverty, injustice and gross inequality persist in our world, none of us can truly rest."

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Dynamique Spatio-Temporelle de L'occupation du sol et de son Implication à la Sécurité Alimentaire en Zone Cotonnière du Mali

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Résumé

La zone cotonnière du Mali est soumise à une pression anthropique très forte. Depuis plusieurs décennies, la forte croissance démographique cumulée avec l'introduction des cultures de rente et la vulgarisation de nouvelles techniques agricoles ont entrainé une modification de l'espace. Donc pour satisfaire les besoins alimentaires, les exploitations agricoles restent dans une logique extensive pour assurer l'autosuffisance alimentaire. C'est dans cette optique que le présent article se fixe comme objectif d'évaluer la dynamique d'occupation du sol et son implication sur la sécurité alimentaire dans les terroirs de Benguéné et Ziguéna dans la zone cotonnière. Pour ce faire un jeu d'image Landsat acquise durant quatre période (1987, 1998, 2009 et 2018) ont été utilisés pour quantifier la dynamique spatio-temporelle des unités d'occupation du sol. Les données issues des Recensements Généraux de la Population et de l'Habitat (GPH) ont été utilisées pour faire une projection de la population en 2018 afin d'estimer les besoins céréaliers selon la norme FAO pour les différentes dates de recensement et de leurs mettre en lien avec la dynamique d'occupation du sol. Les résultats issus de ces classifications ont été intégrés dans une approche de modélisation en utilisant la chaine CA-Markov pour comprendre la dynamique future de l'occupation du sol. Les résultats révèlent que de façon générale la dynamique d'occupation du sol est fortement dépendante des besoins alimentaires et qu'à l'horizon 2028 les terroirs seront confrontés à un problème de saturation d'espace agricole. Dans un système de production peu intensif ou les terroirs sont quasis saturer, les producteurs seront contraints de développé d'autres stratégies pour assurer la sécurité alimentaire à savoir une forte intensification des systèmes de production s'inscrivant dans une démarche d'agroécologie, le développement d'autres activités génératrices de revenue (AGR) et aussi de promouvoir la planification familiale. Les résultats tentent aussi de mettre la lumière sur les pratiques actuelles en termes de gestion durable des ressource naturelles et des stratégies de sécurité alimentaire face aux défis d'atteinte des objectifs de développement durable (ODD), plus spécifiquement les indicateurs des objectifs 2, 9 et 15 des

ODD.

Mot clés: Pression anthropique, Dynamique spatiale, sécurité alimentaire, Modélisation

Introduction

La zone cotonnière du Mali est soumise à une pression anthropique et animale très forte. Depuis plusieurs décennies, la forte croissance démographique cumulée avec l'introduction des cultures de rente comme le coton et l'arachide et la vulgarisation de nouvelles techniques agricoles ont entrainé une modification de l'espace. Donc pour satisfaire les besoins alimentaires, les exploitations agricoles restent dans une logique extensive pour assurer l'autosuffisance alimentaire.

La sécurité alimentaire se définit comme l'accès permanent de tous aux denrées alimentaires nécessaires pour mener une vie saine et active. Par cette définition, la réalisation de la sécurité alimentaire reste un défi majeur à relever pour la zone cotonnière qui constitue la principale région agricole du Mali (Dembélé et Staatz, 2010). Depuis quelques décennies, et ce malgré d'importants progrès accomplis en matière de gestion et de prévention des crises alimentaires, le pays traverse des crises alimentaires dont les origines sont diverses. Certaines crises sont conjoncturelles, d'autres ont des causes structurelles (Hitimana et al., 2008). Le Mali dispose d'un important potentiel agro-sylvo-pastoral et halieutique mais n'arrive pas à couvrir entièrement ses besoins alimentaires et atteindre un niveau de sécurité alimentaire satisfaisant et durable (Sanogo, 2017). Bien qu'aucune crise alimentaire majeure ne soit survenue depuis les années 1983-1984, le Mali vit dans une situation d'insécurité alimentaire chronique liée à la pauvreté endémique, au caractère rudimentaire des systèmes de production (CSA, 2005). Depuis l'indépendance en 1960, les cultures de rente telles que le riz et le coton, plus encadrées par les services d'appui technique, ont connu des augmentations considérables de rendement (riz 3.33 t/ha et coton 1,03 t/ha en 2017), tandis que les rendements des cultures vivrières pluviales (mil 0.88 t/ha et sorgho 0.89 t/ha en 2017 etc.) ont évolué timidement au cours des 50 dernières années, bien qu'elles soient la base de l'alimentation de plus de 80% de la population (Institut d'Économie Rurale, 2020). La superficie totale cultivée en céréales (riz, mil, sorgho, maïs, fonio, blé et orge) est passée de 1,6 millions d'hectares en 1984-1985 à 3,9 millions hectares en 2008-2009, elle a donc plus que doublée en l'espace de 25 ans. On estime le taux de croissance moyenne des emblavures à 2,2% par an dans l'ensemble de 1990 à 2009 (CSA, 2011). En 25 ans, la production de céréale a presque triplé au Mali, passant de 1,1 million de tonnes au début des années 80 à 2,7 millions de tonnes en 2002-2004 (Egg et Wade, 2006). Donc la production agricole globale a augmenté pour répondre à l'accroissement de la demande, mais en accroissant les surfaces emblavées, plutôt qu'en intensifiant. La très grande majorité des systèmes de production agricole sont restés dans une logique extensive par la dynamique d'occupation du sol, qui nécessite toujours plus de terres, notamment au détriment des pâturages et des espaces de cueillettes (Gautier, Gazull and Belières, 2007). C'est dans cette optique que nous nous sommes interrogés gu'avec la forte croissance démographique dans la zone cotonnière du Mali, la dynamique d'occupation du sol contribue-t-elle a assuré la sécurité alimentaire de sa population?

Des études ont été mener pour évaluer la dynamique d'occupation du sol à travers les images satellitaires et la forte pression anthropique sur les ressources naturelles (activités agricole). Ainsi Cuny et Sorg, (2003) dans une étude réalisée dans la commune de Sorobasso située dans le vieux bassin cotonnier, a permis de montrer à l'aide des images satellitaires, qu'au cours des

cinquante dernières années l'évolution des paysages forestiers est fortement lié à la dynamique agricole induit par le coton. Les résultats révèlent aussi que l'expansion territoriale agricole a été plus importante que la croissance démographique. Ces constats ont été faites par Ballo et al., (2016) dans une étude en utilisant les images Landsat, les résultats de cet article conclu que la dynamique de l'augmentation de la superficie agricole et de diminution de la végétation est fortement liée à l'évolution démographique. Mais par contre Fane, (2015) avec la même méthode dans une étude dans la commune rurale de Wateni, trouve que malgré la forte pression anthropique sur les ressource naturelle, la disponibilité des ressources est relativement important et rend atypique la dynamique de l'espace dans la commune. A l'instar de ces résultats ci-dessus et parallèlement a des travaux similaires (Issiaka, Arouna et Imorou, 2016; Mamane et al., 2018; Thierry et al., 2018; Zakari et al., 2018; Sall et al., 2019) qui ont été mener dans la sous-région pour évaluer la dynamique d'occupation du sol à partir des images satellitaires et la forte pression anthropique sur ces ressources, ces études ne tiennent pas compte de la simulation de l'état futur de l'occupation a un horizon (échelle d'année) et le lien direct des besoins alimentaires grandissant en fonction de celle-ci (occupation du sol). C'est partant de ces travaux antérieurs que cet article se fixe comme objectif d'évaluer encore la dynamique d'occupation du sol à partir des images satellitaires de type Landsat et son implication sur la sécurité alimentaire dans les terroirs de Benguéné et Ziguéna dans la zone cotonnière

Matériels et Méthodes

Présentation des Sites D'études

Cette étude a été conduite deux (2) villages de la zone cotonnière, il s'agit de Benguéné vieux bassin cotonnier et Ziguéna dans la zone Bougouni-Sikasso.

Benguéné en zone semi-aride au Nord : La zone dans laquelle est située le village se trouve entre les isohyètes 800-1000 mm. Cette zone relève du vieux bassin cotonnier. Les effets conjugués de la péjoration climatique et la forte emprise agricole constituent une menace pour les ressources naturelles de la zone. Les terres cultivées occupent plus de la moitié du terroir.

Ziguéna en zone de transition au centre : cette zone est située entre les isohyètes 1100-1200 mm. La proximité de la zone des centres urbains (Sikasso, Kignan) augmente le facteur de pression démographique. Les meilleures terres du village de Ziguéna sont exploitées pour la culture de contre-saison, une menace pour les ressources naturelles en général et pastorales en particulier (Kone, 2017).



Figure 1: Présentation des zones d'études Source : MDRI et SotubaGIS

Données

Les données utilisées sont essentiellement des images satellitaires de type Landsat. Ces images téléchargées couvrent une période de 30 ans avec un intervalle de 10 ans, la date d'acquisition de ces images varie d'octobre à décembre en fonction de la disponibilité. La résolution spatiale est de 30 mètres et les capteurs sont de type TM et OLI/TIRS.

Les données démographiques issues des différents recensements généraux de la population et de l'habitat (RGPH) que le Mali a connue (1976, 1986, 1998 et 2009) ont été utilisées pour projeter la population de 2009 et d'estimé les besoins céréaliers de la population selon la norme FAO qui est de 2014 kg/personne/an.

Méthodes

Analyse Diachronique

Deux méthodes de traitement d'image couplées ont été adoptées. Il s'agit de la classification supervisée en utilisant l'algorithme de maximum par vraisemblance (Ballo et al., 2016; Souley Yero, 2008), les résultats obtenus de la classification supervisée ont été soumis à la méthode d'interprétation visuelle afin d'apporter d'éventuelle correction d'apparence des classes. La méthode d'interprétation visuelle des images permet de caractériser les principaux objets présents : sols, végétations, eaux, etc., d'une manière fidèle, systématique et exhaustive par leur

comportement spectral. L'interprétation visuelle a été efficace grâce à la composition colorée par vraie couleur (rouge-vert-bleu) et par fausse couleur (exemple : infrarouge-rouge-vert, proche infrarouge- infrarouge -rouge). Les unités d'occupation obtenues à l'issu du traitement sont entre autres : la zone agricole (champs et jachère récente), la végétation dense (composé de galeries forestières, savanes boisées, savanes arborées et le bois sacré), la végétation moins dense (essentiellement des savanes arbustives en général dernier stade de dégradation des savanes boisées).

Statistiques de la Dynamique Spatiale

Après la méthode de traitement des images Landsat, les statistiques d'évolution de l'occupation des sols ont été calculées à travers l'équation (N°2) proposée par la FAO (1996) et celle de Bernier (1992) (N°3) couramment employées pour mesurer la croissance des agrégats macroéconomiques entre deux périodes données (Hamidou et al., 2012; Issiaka et al., 2016; Kpedenou et al., 2017; Soro et al., 2014).

$$Tg = \frac{S_2 - S_1}{S_1} \times 100$$
 (2)

Tg : Taux global de croissance ; S1 : la surface d'une classe d'unité de surface à la date t1 ; S2 : la superficie de la même classe d'unité de surface à la date t2

$$Tc = \frac{\ln S_2 - \ln S_1}{(t_2 - t_1) \times \ln e} \times 100$$
 (3)

Tc : le taux de croissance annuelle ; S1 : la surface d'une classe d'unité de surface à la date t1 ; S2 : la superficie de la même classe d'unité de surface à la date t2 ; Ln : le logarithme népérien et e la base des logarithmes népériens (e=2,71828)

Modélisation

Cette étape de la démarche nous conduit à prévoir les changements futurs en 2028, pour autant que le contexte considéré pour ces modèles soit encore pertinent dans le futur. Le type de modèle appliqué dans cette recherche est celui faisant appel aux chaines de Markov. La démarche consiste d'abord à faire l'analyse de la chaine de Markov qui est un processus qui permet de simuler l'état futur de l'occupation du sol en se basant sur son passé puis l'application des automates cellulaire qui tienne compte de la contiguïté spatiale d'un pixel par rapport à un groupe de pixels.

Evaluation des Besoins Alimentaires

Les besoins alimentaires en céréale ont été estimés selon la norme FAO qui est de 214 kg de céréales/personne/an et à partir des données de recensement général de la population et de l'habitat (1987, 1998 et 2009). Pour les besoins de 2018 ainsi que les besoins futur (2028) en

absence de données nous avons procédé à la projection de la population. Pour cela nous avons d'abord procédé au calcul du taux d'accroissement intercensitaire (formule 1):

$$r = \sqrt[t]{\left(rac{Pn+a}{Pn}
ight)} - 1$$
 (1)

r : taux d'accroissement naturel (TAN) ; t : intervalle de temps entre deux recensements ; Pn+a : population de l'année 2009 ; Pn : population de l'année 1998

Puis nous avons procédé au calcul de la projection avec la formule ci-dessus

$$Pn = Po(1 + r)^n$$
 (2)

Pn : la population ; Po : la population initiale ; 1 : le chiffre constant ; r : le taux d'accroissement naturel ; n : le nombre d'année entre la population de départ (2009) et la population d'arrivé (2018).

Résultats

Dynamique D'occupation du Sol

Dynamique D'occupation du Sol à Benguéné

La figure ci-dessous présente la situation de l'occupation du sol du terroir de Benguéné en 1987, 1998, 2009 et 2018. Elle permet de percevoir, à travers ces différentes cartes, les différents états d'occupation du sol des années retenues dans le cadre de cette étude.



Source : Landsat Figure 2: Statistiques de la dynamique d'occupation du sol de 1987, 1998, 2009 et 2018 dans le terroir de Benguéné

En 1987, la végétation naturelle était la classe la plus dominante du terroir. La végétation dense occupait une superficie de 1467,87 hectares soit 40,26 % du terroir. La végétation moins dense quant à elle occupait une superficie de 1039 hectares soit 28,52 % du terroir. Celle-ci était suivie

de la zone agricole qui occupait une proportion de 30,55 % du terroir soit 1113,61 hectares, c'était la plus petite unité d'occupation du sol dans le terroir de Benguéné à l'époque (Figure 2).

La situation de l'occupation du sol de 1998 montre toujours une domination de la végétation naturelle malgré une légère augmentation de la zone agricole (Figure 2). Cette superficie agricole est passée à 1364,81 hectares soit 37,44 %. La timide progression de la zone agricole s'est faite essentiellement sur la végétation dense. Elle a régressé avec une superficie de 1124,4 hectares soit 30,84 % du terroir. La végétation moins dense a subi une légère augmentation avec une superficie de 1128,34 hectares soit 30,95 % de la superficie du terroir. Cette légère augmentation de la végétation moins dense découle de la dégradation de la végétation dense.

En 2009, la situation de l'occupation du sol révèle que la zone agricole a connu une progression importante avec une superficie de 1671,97 hectares soit 45,86 % du terroir. De façon générale la végétation naturelle demeure toujours la plus grande unité d'occupation du sol. La surface de la végétation dense était estimée à 1008,78 hectares soit 27,67 % du terroir. La végétation moins dense avait une superficie de 934,4 hectares soit 25,63 % du terroir (Figure 2).

En 2018, la zone agricole est devenue la plus grande unité d'occupation du sol avec une progression importante. Elle atteint une superficie de 1911,32 hectares et occupait 52,43 % soit plus de la moitié du terroir. L'extension de la surface agricole a été faite essentiellement au détriment de la formation naturelle. La végétation dense occupe une superficie de 953,75 hectares avec taux d'occupation de 26,16 % du terroir. La végétation moins dense occupe ainsi une superficie de 743,13 hectares soit 20,38 % de la surface du terroir (Figure 2).

Dynamique d'occupation du sol à Ziguéna

La (Figure 3) illustre la situation de l'occupation du sol du terroir de Ziguéna des années 1987, 1998, 2009 et 2018.



Source : Landsat Figure 3: Statistiques de la dynamique d'occupation du sol de 1987, 1998, 2009 et 2018 dans le terroir de Ziguéna

La Figure 3 fait ressortir l'état de la dynamique de l'occupation du sol de 1987-2018 à Ziguéna. La situation de l'occupation du sol en 1987 à Ziguéna révèle de façon générale que la végétation

naturelle était assez appréciable. La surface de la végétation dense était estimée à 2832,57 hectares soit 44,95 % du terroir. La végétation moins dense occupait 1651,21 hectares soit 26,2 % de la superficie total. A l'époque la zone agricole suivait la végétation naturelle avec une superficie de 1778,43 hectares soit 28,22 % du terroir. La surface eau venait en dernière position avec une surface estimée à 28 hectares soit moins 1 % du terroir (Figure 3).

En 1998, la végétation naturelle était toujours la classe la plus dominante malgré la progression de la zone agricole. La végétation moins dense a subi une légère augmentation de superficie résultant de la dégradation de la végétation dense. La formation naturelle mesurait 2301,5 hectares soit 36,52 % du terroir pour la végétation moins dense. La végétation dense occupait une superficie de 1779,2 hectares soit 28,2 % de la surface totale du terroir. La zone agricole est passée à une superficie de 2146,1 hectares soit 34 % du terroir. Malgré la progression de la surface eau elle est restée la plus petite unité d'occupation du sol avec une superficie de 60,08 hectares soit près de 1 % de la surface totale (Figure 3).

L'analyse de la situation de l'occupation du sol de 2009 révèle que la zone agricole continue de progresser contrairement à la végétation naturelle. La végétation moins dense passe à 31,65 % soit 1993,9 hectares. La végétation dense est passée à 25,46 % soit 1604,34 hectares. La zone agricole quant à elle passe à 2524,4 hectares soit 40 % du terroir. La surface eau a connu une extension malgré qu'elle soit la plus petite unité d'occupation du sol, elle est passée à 157,38 hectares soit 2,5 % du terroir (Figure 3).

En 2018 la situation de l'occupation du sol révèle une forte domination de la zone agricole qui a connu une augmentation exponentielle de surface au fil des années, elle atteint une superficie de 3640,4 hectares soit 57,78 % du terroir. La végétation naturelle suit une logique régressive. La végétation moins dense est passée à 1454 hectares soit 23,1 % du terroir. Quant à la végétation dense elle a régressé à 1123,82 hectares soit 17,84 % du terroir. De façon générale la végétation naturelle a régressé pour faire place à la zone agricole. La surface eau a aussi régressé et est passé à 42,39 hectares soit 0,67 % du terroir compte tenue des effets de la saisonnalité (Figure 3).

Statistique de la Dynamique de L'occupation du Sol

Statistique de la Dynamique de L'occupation du Sol à Benguéné

Taux de changement annuel global 1987-2019

La zone agricole de Benguéné a connu une progression annuelle de 0,6 % soit une croissance annuelle de 7,14 hectares durant la période 1987-2018 (Source : Landsat

Figure 4).

Ceci est contraire à la végétation naturelle qui régresse d'année en année au profit de la surface agricole. La végétation dense régresse annuellement de 0,8 % de sa superficie soit une réduction annuelle de 11,9 hectares. La végétation moins dense a perdu annuellement 0,1 % de sa superficie, ce qui équivaut à une régression de 1,1 hectare par an entre 1987-2018.



Source : Landsat Figure 4:Taux de changement annuel global 1987-2019 à Benguéné

Taux de Changement Global 1987-2019

Le taux de changement global montre que la zone agricole de Benguéné a connu une progression remarquable (

Figure 5). Elle a augmenté de 71,6 % de sa superficie initiale correspondant à une croissance globale de 797,7 hectares durant la période 1987-2018. Ces évolutions remarquables ont été faites sur la végétation naturelle qui se voit diminuer de superficie. La végétation dense a perdue globalement 49,4 % de sa superficie initiale soit une régression globale de 724,7 hectares durant la période 187-2018. De même la végétation moins dense a aussi perdu 8,3 % de sa superficie soit 86 hectares durant la même période.



Source : Landsat Figure 5:Taux de changement global 1987-2019 à Benguéné Statistique de la dynamique de l'occupation du sol à Ziguéna

Taux de Changement Annuel Global 1987-2019

La Figure 6 illustre le changement annuel global. La surface agricole a subi une forte progression annuelle de 0,9 % soit une augmentation de 15,1 hectares par an durant la période 1987-2018. De même la surface en eau a progressé annuellement de 0,5 % soit une extension de 0,1

hectares par an. La végétation naturelle quant à elle perd de superficie au détriment des autres unités d'occupation du sol. La végétation dense régresse de 1,1 % par an soit 31,1 hectares. La végétation moins dense a aussi perdu annuellement 0,2 % de sa surface soit une réduction de 2,5 hectares par an pendant la période 1987-2018.



Source : Landsat Figure 6:Taux de changement annuel global 1987-2019 à Ziguéna

Taux de changement global 1987-2019

Les taux de changements globaux durant la période 1987-2018 nous montre que la surface agricole a augmenté de 104,7 % soit une progression de 1862 hectares (**Figure 7**). Suivie de la surface en eau qui a subi une extension de 51,4 % avec une augmentation de 14,4 hectares. Ces différentes évolutions ont été faites de façon générale sur la formation naturelle. La végétation dense a perdu 60,3 % de sa surface soit 1708,7 hectares. La végétation moins dense a globalement perdu 11,9 % de sa superficie soit une réduction de 197,2 hectares durant période d'étude.



Source : Landsat Figure 7:Taux de changement global 1987-2019 à Ziguéna

Modélisation de la Dynamique Spatio-Temporelle de L'occupation du Sol

Matrice de Transition des Unités de L'occupation du Sol de Benguéné 1998 à 2009
Les résultats de la matrice de transition révèlent que 1411,71 hectares de la surface agricole sont restés constante avec une stabilité de 74 % et 499,4 hectares ont changés d'état soit un taux de changement de 26 %. Le bâti rural a connu une stabilité de 85 % de sa surface initiale soit 31,02 hectares contre un changement d'état de 5,48 hectares avec une proportion de 15 %. La végétation naturelle a été l'unité la moins instable durant cette période. La végétation dense a été stable à 32 % soit 237,46 hectares contre une variation de 68 % de sa superficie initiale soit 505,78 hectares. Quant à la végétation elle a été stable à 65 % (616,07 hectares) contre un changement d'état de 35 % (337,77 hectares). Cette forte instabilité de la végétation naturelle a été faite en faveur de la surface agricole.

Unités	Agricole	Bâtis	Bois sacré	Végétation dense	Végétation moins dense	Total 1998
Agricole	1411,71	16,67	0	373,55	109,27	1911,2
Bâtis	1,37	31,02	1,37	1,37	1,37	36,5
Bois sacré	0,04	0,04	0,99	0,04	0,04	1,15
Végétation dense	342,78	0,18	0	237,46	162,82	743,24
Végétation moins dense	105,23	0,37	0	232,1	616,07	953,77
Total 2009	1861,13	48,28	2,36	844,52	889,57	3645,86

Tableau 1: Probabilité de Transition à Benguéné Entre 2009-2018

Source : Landsat

Matrice de transition des unités de l'occupation du sol de Ziguéna 1998 à 2009

Les statistiques de la matrice de transition révèlent que la surface agricole a été constant à 74 % de sa superficie initiale soit 2689,3 hectares contre un changement d'état de 26 % (950,77 hectares). Le bâti rural a connu une stabilité de 85 % (33,79 hectares) contre une variation de 15 % soit 6,16 hectares. La surface en eau a été moins stable soit 13 % (5,35 hectares) de sa surface initiale et une variation importante de 87 % soit 37,06 hectares. La végétation naturelle a été de façon générale la moins constante. La végétation dense est restée stable à 32 % (364,08 hectares) contre une variation de 68 % (759,93 hectares) de sa surface initiale. La végétation moins dense est restée constante à 38 % (547,44 hectares) contre un changement d'état de 62 % (906,7 hectares).

Tableau 2:Probabilité de transition à Ziguéna entre 2009-2018

Unités	Agricole	Bâtis	Eau	Végétation dense	Végétation moins dense	Total 1998
Agricole	2689,3	41,1	2,1	267,09	640,46	3640,07
Bâtis	6,16	33,79	0	0	0	39,95
Eau	36,85	0	5,35	0,01	0,2	42,41
Végétation dense	563,4	0,15	0,01	364,08	196,37	1124,01
Végétation moins dense	624,81	5,53	0	276,37	547,44	1454,15
Total 2009	3920,5	80,57	7,46	907,55	1384,47	6300,59

Source : Landsat

Bilan de la stabilité de la dynamique d'occupation du sol

Dans les terroirs d'étude spatialement 69 % (2502,2 hectares) de la superficie est resté stable à Benguéné contre 40 % (2546,8 hectares) à Ziguéna. Les surfaces en régression sont de 24 % à Benguéné soit 887,6 hectares et de 43 % (2714,7 hectares) à Ziguéna. Les zones de progressions sont respectivement de 7 % (255,9 hectares) et 16 % (1040 hectares) à Benguéné et Ziguéna. De façon générale les zones de régression sont beaucoup plus importantes Ziguéna contrairement à Benguéné. Ceci explique une forte réserve des surfaces agricole à Ziguéna et possible saturation des espaces agricoles dans le terroir de Benguéné.



Source : Landsat Figure 8: Statistique de la stabilité des unités d'occupation du sol

Simulation de L'occupation du Sol à L'horizon 2028

Simulation de L'occupation du Sol de Benguéné à L'horizon 2028

La simulation de l'occupation du sol annonce une forte anthropisation pour un terroir quasiment déjà sous l'emprise agricole avec environ 75 % du terroir (Figure 9). La zone agricole connaîtra une forte extension de sa superficie initiale de 2018. La surface agricole passera de 1911,32

hectares (52,4 %) en 2018 à 2050,1 hectares (56,2 %) en 2028. La végétation naturelle perdra de superficie au profit de la zone agricole. La végétation dense passera de 743,1 hectares (20,4 %) à 624,8 hectares (17,1 %). La végétation moins dense passera 953,8 hectares (26,2 %) à 929,1 hectares (25,5 %) durant la même période.



Source : Landsat Figure 9: Comparaison de la carte d'occupation du sol de 2018 et la carte de prédiction à l'horizon 2028 dans le terroir de Benguéné

Simulation de l'occupation du sol de Ziguéna à l'horizon 2028

Le bilan global de la simulation de l'occupation du sol prévoie une forte anthropisation de l'espace de Ziguéna (Figure 10). En effet la surface agricole connaîtra une hausse considérable de superficie dans le futur (2028). La surface agricole passera de 3640,4 hectares en 2018 (57,8 %) à 3937,45 hectares (62,5 %) en 2028. Cette évolution de la classe ci-dessus sera faites sur la végétation naturelle, qui a son tour diminuera de superficie. La végétation dense passera de 1123,8 hectares (17,8 %) en 2018 à 906 hectares (14,4 %) en 2028. La végétation moins dense passera de 1454 hectares (23,1 %) en 2018 à 1385 hectares (22 %). La surface eau perdra aussi de superficie due probablement aux effets futurs de la saisonnalité.



Source : Landsat Figure 10: Comparaison de la carte d'occupation du sol de 2018 et la carte de prédiction à l'horizon 2028 dans le terroir de Ziguéna

Pression Démographique et Besoins Spécifiques des Populations

Au Mali comme dans toutes les autres régions d'Afrique subsaharienne, les céréales sèches (mil, maïs, sorgho) constituent la base des consommations des exploitations agricoles familiales. Les besoins en céréale sèche (mil, maïs, sorgho) sont estimés à 139 kg par personne et par an,

celles-ci sont complétée par le riz avec un besoins de 79 kg par personne et par an selon les statistiques de la FAO (Figure 11). Au total les besoins céréalières estimés par la norme FAO est de 214 kg par tête et par an. Comme nous pouvons le constater plus la population croit plus les besoins spécifiques de ces céréales augmentent. Les besoins céréaliers constituent un facteur important de la dynamique d'occupation du sol dans les systèmes de production peu intensif comme celui des sites d'études retenu (Benguéné et Ziguéna).



Source : RGPH et FAO Figure 11: Estimation de la variabilité des besoins en céréale selon la norme FAO

Dynamique D'occupation des Terres Agricole et Sécurité Alimentaire

La dynamique d'occupation des terres agricole (superficies cultivées) du terroir de Benguéné varie en fonction des besoins alimentaires (céréales). Elle est la principale stratégie de réalisation de l'autosuffisance alimentaire. Cependant cette autosuffisance ne pourra pas se faire continuellement par le biais des superficies cultivables puisqu'elles s'épuiseront dans un futur proche c'est-à-dire à partir de 2028 (Figure 12). Les exploitations agricoles seront contraintes de développées d'autres stratégies pour pouvoir assurer autosuffisance céréalière.





Dans le terroir de Ziguéna, la dynamique d'occupation des superficies cultivées est fortement dépendante des besoins alimentaires (céréalière) (Figure 13). Les superficies cultivées augmentent en fonction des besoins alimentaires de la population. La disponibilité foncière (superficie cultivables) de Ziguéna laisse entrevoir une continuité de réalisation de l'autosuffisance par l'extension des superficies cultivées jusqu'en 2038. Mais au-delà de cette date les superficies cultivables ne seront plus en mesure de couvrir les besoins céréaliers, donc les exploitations agricoles seront contraintes de développer d'autres stratégies pour la réalisation de la sécurité alimentaire en termes de disponibilité alimentaire.





Discussion

Les tendances générales observées au niveau de la dynamique d'occupation du sol dans les deux (2) sites (Benquéné et Ziguéna) sur les trois (3) dernières décennies est une forte augmentation des superficies agricoles au détriment de la formation végétation, ces résultats sont identiques aux travaux effectués par Ballo et al., 2016; Fane, 2015; Ngo et al., 2018. Les résultats de la prédiction de l'état futur de l'occupation du sol (modélisation) révèlent qu'à l'horizon futur (2028), pendant que les surfaces agricoles et bâtis s'étendront, les superficies de la végétation naturelle connaîtront une forte régression. Ces tendances sont observées dans les études menées par Dembele, 2019; Oloukoi et Mama, 2006; Sall et al., 2019. Les résultats de cette étude prouvent également que l'amélioration de l'autosuffisance alimentaires (céréalières) est le fruit de la dynamique d'occupation des terres agricole qu'a connue les sites durant les trente (30) dernières années, c'est-à-dire une forte augmentation de la superficie cultivée plus que le rendement résultant essentiellement de l'augmentation des besoins céréalières et qui reste la principale stratégie d'autosuffisance. Cette tendance est conforme avec celui de Ballo et al., 2016), qui affirme que l'augmentation de la population est fortement corrélée avec la production et aussi avec la superficie cultivée, tandis qu'elle est en faible corrélation avec le rendement par hectare.

Conclusion

L'étude a permis de mettre en exergue des éléments de réponses à des facteurs liés à la dynamique d'occupation du sol et de la stratégie de réalisation de la sécurité alimentaire dans un contexte de forte croissance démographique. Deux principaux types de données ont été utilisés. il s'agit des images Landsat et des données du RGPH. Les dynamiques d'occupation du sol passées se sont faites principalement au profit des surfaces agricoles, résultant essentiellement de l'augmentation des besoins alimentaires. La principale stratégie constatée pour assurer l'autosuffisance alimentaire soulève des questions quant à la vulnérabilité future des exploitations agricole face au risque de l'insécurité alimentaire puisque l'accroissement de la production ne pourra pas se faire éternellement par l'augmentation des surfaces. Les résultats de ces analyses montrent à quel point les pratiques actuelles compromettent les défis d'atteinte des ODD. Les résultats de cette étude nous a permis de dégager des pistes de solution face à la vulnérabilité future des exploitations agricoles au risque de déficit céréalières, il s'agit donc : d'intensifier l'agriculture pour booster les rendements des cultures : d'orienté le maximum de producteur vers d'autres activités génératrices de revenu différent de l'agriculture et de diminuer le taux de croissance démographique par la planification familiale afin de réduire la pression sur les ressources naturelles.

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Assessment of Sustainable Food Systems in Mountain Regions of India Through Climate Smart Agriculture During Covid-19 Pandemic: The Case Study of AI for Rural

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Abstract

The Sustainable Development Goal (SDG) 2.4 states that "By 2030, ensure sustainable food production and resilient agricultural practices." As per the Food and Agriculture Organization of the United Nations FAO-UN (2018): one in every three mountain people in developing countries are vulnerable to food insecurity. The largest source of livelihood in India is Agriculture and about 70 percent of its rural households still depend on it. Indian mountain agriculture has always been tagged with some basic limitations including remoteness, inaccessibility, marginality, and vulnerability (FAO, 2019). Farming in hilly areas is mostly rain-dependent and faces several constraints such as irrigation facilities, climatic limitations, infrastructure restrictions. management limitations and socio-economic restraints have impacted Indian agrarian society and resurfaced bottlenecks in current farming practices, particularly in vulnerable regions.

To meet the needs of current and future generations, it is critical to accelerate implementation and track the development of sustainable food systems so that we can improve the livelihoods of marginal households in the rural and mountain regions. In this research paper, we will be doing extensive research on how Climate-Smart Agriculture (CSA) will help farming systems achieve increased productivity and build resilient frameworks to tackle climate change. We also intend to investigate the erratic effects of climate change, i.e., droughts, irregular rainfall, and create pathways for better infrastructure. Finally, we will also examine how the digital solutions, through gamification, assist farmers in making informed crop selection decisions and reducing Greenhouse emissions.

Keywords: Artificial Intelligence, Sustainable Food Systems, Climate Smart Agriculture, Sustainable Mountain Development, Public and Private Partnerships.

Acronyms

SOFI......The State of Food Security and Nutrition

SDG.....Sustainable Development Goal

IFAD.....International Fund of Agriculture Development

UNICEF......United Nations International Children's Emergency Fund

WFP.....World Food Program

- WHO.....World Health Organization
- PoU.....Prevalence of Undernourishment
- FAO.....Food and Agriculture Organization
- UN.....United Nations
- UNEP-WCMC......UN Environment Program World Conservation Monitoring Centre
- LER.....Land Equivalent Ratio
- GHG.....Greenhouse Gas
- CGIAR.....Consultative Group on International Agricultural Research
- AI.....Artificial Intelligence
- IoT.....Internet of Things
- NITI.....National Institution for Transforming India
- IBM.....International Business Machines
- ICAR.....The Indian Council of Agricultural Research
- IARI.....Indian Agricultural Research Institute
- ML.....Machine Learning
- UAV.....Unmanned Aerial Vehicles
- DL.....Deep Learning
- CSA.....Climate-Smart Agriculture
- SOC.....Soil Organic Carbon
- SAARC.....South Asian Association for Regional Cooperation
- FS.....Food Systems

FGD.....Focus Group Discussion

- ICIMOD......The International Center for Integrated Mountain Development
- RMS.....Resilient Mountain Solutions
- SAPS.....Sustainable Agriculture Practices and System
- FOCUS......Fostering Climate Resilient Upland Farming Systems
- MoA&FW......Ministry of Agriculture and Farmer' Welfare
- Gol.....Government of India
- MAFAP......Monitoring and Analyzing Food and Agricultural Policies
- AIR.....AI for Rural
- GPS.....Global Positioning System
- OECD.....Organization for Economic Co-operation and Development
- CSE.....Consumer Support Estimate
- PSE.....Producer Support Estimate
- C-D Ratio.....Credit-Deposit Ratio
- RIDF.....Rural Infrastructure Development Fund
- RBI.....Reserve Bank of India
- KCC.....Kisan Credit Card
- PM-KISAN.....Pradhan Mantri-Kisan Samman Nidhi
- NPJSY.....Neelambar Pitambar Jal Sammridhi Yojana
- PMGSY.....Pradhan Mantri Gram Sadak Yojana
- e-Nam.....Electronic Unified Agricultural Markets
- AIF.....Agriculture Infrastructure Fund

PPPs.....Public-Private Partnerships

CO2.....Carbon Dioxide

FPO.....Farmers Producer Organization

VC.....Value Chain

Introduction

Purpose

Six years ago, we were positive that with transformative methods, the Sustainable Development Goal 2 (SDG 2) i.e., ending hunger, food insecurity, and all forms of malnutrition would be ended by 2030. In the past four publications of The State of Food Security and Nutrition in the world (SOFI), FAO exposed that the world has not been progressing either towards ensuring access to safe, nutritious, and sufficient food for all people (SDG target 2.1) or in the direction of eradicating all forms of malnutrition (SDG target 2.2) (FAO, IFAD, UNICEF, WFP, and WHO, 2021). Conflict, climate variability, extremes, economic slowdowns, downturns, and the Covid-19 pandemic are the major reasons which are making the pathway towards SDG 2 even steeper.



Figure 1: The number of undernourished people in the world continued to rise in 2020

Under the Covid-19 pandemic, the number of people affected by hunger in the world increased abruptly in 2020. After remaining quite unchanged from 2014 to 2019, the Prevalence of Undernourishment (PoU) climbed to 9.9 percent in 2020 as shown in Figure 1. It is estimated around 660 million may still face hunger in 2030 i.e., 30 million more people, had the pandemic

not occurred. There is an increase of 320 million in just one year i.e., one in three people in the world did not have access to adequate food in 2020 as shown in figure 2.



Figure 2: Moderate or severe food insecurity has been climbing slowly for six years

According to the study done by FAO, mountain ecosystems are becoming increasingly fragile and degraded, under the pressure from changes to land use and climate, overexploitation, and other factors that threaten living and food security. Around 275 million rural people vulnerable to food insecurity are estimated to live in mountain areas globally. The Mountain partnership founded in 2002, addresses the challenges facing mountain regions by tapping the wealth and diversity of resources, knowledge, information, and expertise, in order to stimulate concrete initiatives at all levels that will ensure improved quality of life and environments in the world's mountain regions (FAO, Mountain Partnership). India is also one among the alliance of partners dedicated to improving the lives of mountain peoples. The standard mountain definition within the UN is the UNEP- WCMC definition to represent the world's mountain environments (Valerie et al., 2000) which is based on altitude and slope which indicates six elevation classes according to the following scheme:

- Class 1: elevation ≥ 4 500 m
- Class 2: elevation 3 500-4 500 m
- Class 3: elevation 2 500–3 500 m
- Class 4: elevation 1 500–2 500 m and slope $\ge 2^{\circ}$
- Class 5: elevation 1 000–1 500 m and slope ≥ 5° or LER > 300 m
- Class 6: elevation 300–1 000 m and LER > 300 m

India has seven major mountain ranges: 1. The Himalayas, 2. Purvanchal range (extension of the Himalayas in the northeast of India), 3. Satpura and Vindhya ranges (Central India, Madhya Pradesh to Maharashtra), 4. Aravalli range (Rajasthan to Haryana), 5. Western Ghats (Gujrat to Southern tip of India), 6. Eastern Ghats (from West Bengal to Tamil Nadu). The Indian Himalayan region is 53.8 million hectares and is a shelter to 34 million people who are majorly hill farming communities that survive on livelihood farming on the insignificant rainfall. Agriculture is the primary sector of the Indian Himalayas contributing 45 percent to the total regional income of the inhabitants. However, more than 90 percent of the farmers in the hill and mountain areas are marginal, cultivating less than one hectare of land (Tej, 1995; Tej, 1999).

In terms of moisture stress, poor soil conditions, and short growing seasons, Indian agriculture faces several constraints as irrigation facilities are barely sufficient, despite having access to sufficient water resources (FAO, 2019). Moving on, there are socio-economic limitations such as smallholdings, ignorance of farmers regarding techniques, poor productivity, pre- and post-production management, marketing networks, labor shortages, and lack of entrepreneurship. Furthermore, climatic limitations include high rainfall and humidity, low temperatures during winter, low light intensity and radiation, floods, and seasonal drought. Moreover, infrastructure restrictions include the lack of road, transport, and communication facilities, lack of post-harvest facilities, and marketing. Adding to that there are management limitations such as extension gaps, poor motivation, awareness, lack of farmer incentives, non-assurance of the minimum price, lack of availability of inputs, lack of credit facilities, and ineffective coordination between various departments connected with agricultural development.



Figure 3: Mountain Agricultural System

Covid-19 has amplified the vulnerabilities of mountain communities that depend on agriculture for survival as shown in figure 3 above. One in each two rural mountain individuals in underdeveloped nations need more food to carry on with a sound life and they are presently managing the effect of the Covid-19 pandemic (FAO and UNCCD, 2020). This study indicates the vulnerability of people especially the smallholders to climate change, food insecurity, and malnutrition in mountain areas. Thus, there is a need for policies to improve the resilience of mountain ecosystems.

Literature Review

Climate Crisis – the increased frequency of extreme weather events such as droughts, floods, and storms are the most challenging issue of our age. Akshit and Raju (2022) mention in their article that less snow, high temperatures have upturned lives in the Himalayan cold desert and also how the changing precipitation has impacted farming. Shagun (2021) mentions in her article that the climate crisis has cost India 5 million hectares of crops in 2021 to the cyclonic storm, flash floods, floods, landslides, and cloudbursts. In another article, Richard (2022) said that unfavorable, unreliable weather hurt agriculture is pushing food prices out of reach across the world. Ram (2021) speaks about the pressures of cultivating tomato off-season and changing climate that is making life difficult for Chittoor's (Andhra Pradesh state) farmers as they were reluctant to take up tomato cultivation. A report on "Natural change impacts on Agriculture in India " (n.d.) states the impact of environmental change on agribusiness could achieve issues with food security and how it could affect a huge piece of the general population. This is also backed up by Anubhab and Kavi (2019) in their papers as well. Another report by Current Science (2016), said that assessing vulnerability to climate change and variability is an important first step in evolving appropriate adaptation strategies to changing climate. Hulya et al., (2021) wrote in their article that the structural aspects of climate vulnerabilities in the context of monsoon failure and how it impacts the already disadvantaged marginal landholders, subsistence farmers, and agricultural workers in rural parts of Tamil Nadu state.

Policies - Climate change alters the agriculture production conditions and food security, increasing the frequency and depth of risk to agricultural production and incomes. A report by FAO (2016) mentions policy-makers who need assistance in identifying risk management options in the agricultural sector that allow them to effectively respond to the climate risks they face while maintaining and enhancing agricultural policy objectives and adopting climate-smart agriculture. One more article by CGIAR Research Program on Climate Change (2016), seeks to bridge the gap between what policymakers already know, and what can work on the grassroots level to improve adaptation, increase productivity, improve livelihoods, and makeup to sustainable development affected by climate change. According to Pritha and Bhagirath (2022), sustainable adaptive capacity-driven policy initiatives to enable efficient adaptation and agrarian welfare are of paramount importance in the Eastern Himalayan foothills of West Bengal, India.

Artificial Intelligence (AI) in Agriculture - AI is a creative tool that simulates human intelligence and ability processes by machines, principally computer systems, robotics, and digital equipment. AI

helps scientists in building robust systems to learn from weather conditions, sense all the data. and analyze them to propose effective solutions for the farmers. Srinivasarao et al., (2020) recommend integrating IoT and AI technologies and using the data that is collected from sensors in the field about soil moisture, weather conditions, fertilization levels, irrigation system, soil composition, and temperature will help in increasing crop production. In an article by Rayda and Mohsen (2021) suggest the importance of AI and ML (Machine Learning) as a predictive multidisciplinary approach to improve the food and agriculture sector. Karim et al., (2021) found that the usage of AI and remote sensing as efficient devices to increase agricultural system yields has improved crop production as well as enhanced instantaneous monitoring, processing, and collection. A Tokyo report on 'AI in agriculture for tackling Social and Environmental changes', (2019) talks about how digitization can be used to transform the current agri-food system in order to face today's climate and challenges with digital and precision agriculture. Parul (2020) in his article, speaks about the initiatives adopted by the Ministry of Agriculture in India highlighting how Al is bridging the gap between conventional agricultural practices and sustainable farming methodology. The government's policy think-tank National Institution for Transforming India (NITI) Aayog decided to partner with leading technology company IBM to develop a crop yield prediction model using AI to provide real-time advisory to farmers, according to a newspaper article in the Economic Times titled 'NITI Aavog ropes in IBM to use AI in Agriculture' (2018). In another newspaper article in India Today, Neetu (2016) mentions that the ICAR through the Indian Agricultural Research Institute (IARI) is developing an indigenous prototype for drone-based crop and soil health monitoring systems that could benefit the farmers abundantly. Thomas et al., (2020) conducted a study testing the effectiveness of various ML algorithms and how it is an important decision support tool for crop yield prediction, including supporting decisions on what crops to grow and what is to be done during the growing season of the crops by using the input features of temperature, rainfall, and soil type. In their book, Parvinder and Amandeep (2022) claim that AI techniques are helping in increasing yield and overcoming limitations, like global warming, excessive use of fertilizers, limited availability of natural resources, plant disease, and water scarcity. Subeesh and Mehta (2022), found that IoT and AI-based systems are capable of enhancing input use efficiency on the farm and smart farming leverages digital technologies to automate agricultural operations in real-time. Elsayed et al., (2021) in an Egyptian journal of remote sensing and space science, illustrate the use of unmanned aerial vehicles (UAVs) and robots in real-time harvesting, seedling, weed detection, irrigation, spraying of agricultural pests, livestock applications, and other applications using IoT, AI, Deep Learning (DL), ML, and wireless communications. A blog in Equinox's drones 'Importance of drone technology in Indian agriculture, farming' (2019-20) speaks about the usage of agriculture drones and how it empowers the farmer to adapt to specific environments and make mindful choices accordingly. Rahul et al., (2020) discusses how AI can improve Indian Agriculture by providing accurate and timely information regarding crops, land, weather, insect, pest, etc. to the farmers; therefore, improving crop productivity.

Climate-smart agriculture (CSA) - CSA as defined and presented by FAO (2013) at the Hague Conference on Agriculture, Food Security, and Climate Change in 2010, contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social, and environmental) by addressing food security and climate

challenges. According to FAO, CSA is composed of three main pillars: 1. sustainably increasing agricultural productivity and incomes; 2. adapting and building resilience to climate change; 3. reducing and removing greenhouse gas emissions. The article 'Climate-smart agriculture: an answer to climate change' (2016) clearly suggests that sustainably increasing agricultural production, adapting to climate change, and reducing emissions are the vital steps for adopting CSA. A study conducted by Juliet et al., (2021) gives insights into the Climate Change scenario in the mountain ranges of the Aravalli district (in Gujrat state) and its impacts on smallholder farmers, the adoption of CSA practices and their challenges, and current policy options and programs. The paper published by Srinivasa et al., (2019) also aims at identifying indicators for measuring climate-resilient agriculture in the Indian subcontinent including the Himalayan mountains and developing a conceptual framework for location-specific policy interventions. Alireza and Ricardo (2020), mention how ML and gamification can be combined and how they can be used in behavioral change efforts by adapting the gamification context and optimizing the gamification tasks in a non-game context.

Contributions of FAO & ICIMOD to Indian Food Systems

Food systems (FS) as defined by FAO, encloses the entire range of associated people and their value-added activities involved in the production, aggregation, distribution, consumption, and disposal of food products that emerge from agriculture, forestry or fisheries, and parts of the broader economic, societal and natural environments in which they are rooted (FAO, 2018). A sustainable food system (SFS) is an FS that delivers food security and nutrition for all so that the economic, social, and environmental bases to generate food security and nutrition for future generations are not compromised.

The SDGs of the United Nations revolve around a sustainable food system. To achieve a sustainable food system, the global food system needs to be updated to be more productive, including all poor and marginalized populations, environmentally sustainable and resilient, and be able to deliver healthy and nutritious diets to all. Encouraging policymakers to see the bigger picture will also help assist multi-stakeholder collaboration and policy alignment at different levels of the FS to address the challenges.

Food systems have the potential to deliver inexpensive, sustainable, and inclusive healthy diets, as well as become a powerful force in the fight against hunger, food insecurity, and malnutrition. Climate change is already affecting food security through increasing temperatures and changing precipitation patterns and is predicted to be increasingly affected by projected future climate change. About 20-35% of total Greenhouse Gas (GHG) is due to the food systems. In 2018, India produced 2,299 million tons of carbon dioxide (CO2). The majority of agricultural GHG emissions occur during the primary production stage, when agricultural inputs, farm machinery, residue management, and irrigation are produced. Supply-side practices also contribute to climate change through crop and livestock emissions, carbon in soil and biomass, and increasing emission intensity in production systems as shown in Figure 4.



Figure 4: Interlinkages between the climate system, food system, and socio-economic system

ICIMOD (The International Center for Integrated Mountain Development) focuses on adaptation to change to overcome the impacts on farming systems, high-value agriculture products, and related value chains for increasing the income of the poor farmers through agriculture and rural enterprises. ICIMOD is contributing to the farming systems' knowledge development, action research for interventions, capacity building, piloting, and providing inputs to policy processes for improving livelihood for mountain farmers.

Under the regional program of adaptation and resilience building, ICIMOD works with HKH region mountain communities to adapt and transform major changes and face persistent problems that exist (Summary of the Hindukush Himalaya, 2019). ICIMOD has adopted is Resilient Mountain Solutions (RMS), an integrated approach to sustainable mountain development (SMD), focusing on climate change, adaptation, resilience, and preparedness for mountain risks (ICIMOD Adaptation and Resilience Building - RMS, n.d.). According to the annual report 2020 (ICIMOD Annual Report, 2020), ICIMOD has demonstrated its resilience and adaptability, focusing our work on the uniqueness of the pandemic impacts on the people and environments in the HKH mountains especially in the Koshi basin ('The Future of the Koshi Basin', n.d.).

ICIMOD has conducted a workshop with the objective of this training to develop participants' understanding of the issues of climate change, adaptation, inclusive value chains, and resiliencebuilding in the agriculture sector ('Regional Training on Building Resilient Agriculture: Solution Packages for Farming Communities', 2019). Regional conference ('Regional Conference on Mountain Agriculture, with Focus on Ecosystem Services, Agri-Extension, and Market Linkages', 2017) focuses on improving mountain livelihoods was an outreach event that resulted in the uptake of knowledge in policy and practice initiatives related to mountain agriculture and also in higher education, training, and research.

FAO aims to help policymakers, administrators, and philanthropists to represent an important alternative to conventional input-intensive agriculture in the context of constraints from climate (Shanal et al., 2021). FAO also addresses the fact that the Indigenous Peoples' FS involves the totality of human agencies (knowledge, strategies, techniques, values, sharing) for the production, generation, utilization, access, availability, stability, and management of food that are nutritious, culturally and spiritually fulfilling, and sustainable for future generations (The White/Wiphala Paper on Indigenous Peoples' food systems, FAO 2021).

FAO's operations in India began in the year 1948 (FAO in India, FAO n.d.). The Strategic Objectives through their alignment into Regional Initiatives and Regional Priorities in India which will be governed by FAO's support are:

- Farm earnings have increased as a result of sustainable and improved agricultural productivity.
- Stronger food and nutrition security systems.
- Enhanced social inclusion, improved skills, and employment opportunity in the agriculture sector

The NITI Aayog, Ministry of Agriculture and Farmers' Welfare (MoA&FW) with FAO have launched the book titled 'Indian Agriculture Towards 2030: Pathways for Enhancing Farmers' Income, Nutritional Security and Sustainable Food and Farm Systems'. A National Conference in January 2021 aimed to address how the Green Revolution transformed India from a food-deficit nation to a food-surplus, export-oriented country and how the country now is facing second-generation problems, especially related to sustainability, nutrition, the adoption of new agricultural technologies, and income levels of the population dependent on farming ("INDIAN AGRICULTURE TOWARDS 2030: Pathways for Enhancing Farmers' Income, Nutritional Security and Sustainable Food Systems", FAO 2021).

FAO has also contributed to the project in 2018, which was about 'Strengthening Institutional Capacities for SMD in the Indian Himalayan Region (Indian Himalayan Region)' (FAO in India, FAO project list). Another Project 'Implementing the Monitoring and Analyzing Food and Agricultural Policies (MAFAP) Program in India' was undertaken under the FAO support in 2019.

The Indian government and the private sector are joining hands to create climate-resilient villages and are now taking into account that the long-standing policies for agriculture inputs (power and fertilizers) and price support are imposing significant damage on the environment. If this continues to grow without mitigation through the right policies and corrective measures, this issue will be a big challenge in the years to come especially in the over-exploited areas which are mostly rural and mountainous parts.

Jharkhand and their Adaptation Strategies

The FGDs (focus group discussions) to examine the perception regarding climate change data revealed that the Sauria Paharia community (Suparna et al., 2021), a vulnerable indigenous mountainous community (they are smallholder farmers facing food and nutrition insecurity and have limited resources to cope with climate change) attributed local climatic variability in the form of low and erratic rainfall with long dry spells, very less crop productivity, diversity and food obtainable from the forests and water bodies. The major reason reported for the reduced household income was declining agroforestry-produce which led to a shift from livelihood agricultural economy to migratory unskilled wage laboring which in turn led to household food insecurity.

Dr. R. K. Singh, Additional Director General (Food & Fodder Crops) of ICAR said that the next green revolution will come from the country's eastern region and Jharkhand with its rich biodiversity will play an important role on this front ('Jharkhand to play a key role in next green revolution: Experts', 2018). The state is part of agro-climatic zone VII, which includes the Eastern Plateau and Hilly region, and is divided into three subzones: IV. Central and North-Eastern Plateau, V. Eastern Plateau, and VI. South-Eastern Plateau. The Sauria Paharia people are a Dravidian ethnic people of the Indian state of Jharkhand. They are found mostly in the Santhal Parganas (one of the divisions of Jharkhand) region in the Rajmahal Hills.



Figure 5: Agroclimatic zones of Jharkhand

The adaptation strategies during adverse situations adopted by the Sauria Paharia community to cope with climate variability included the use of climate-resilient indigenous crop varieties for

farming, seed conservation, and availability of indigenous forest foods and weeds for consumption (Suparna et al., 2021). Promoting sustainable adaptation strategies, with adequate knowledge and technology, have the potential to improve farm resilience, income, household food security, and dietary diversity in this population and can be scaled to other mountainous regions in India as well.



Figure 6: Sustainability in Food systems

In order to achieve SFS and educate the farmers, the development has to take place simultaneously in social, economic and environmental dimensions. The FS is considered sustainable economically if the activities conducted by the support system provider are economic value-added for all categories of stakeholders say food supply improvements for consumers etc. Under the social dimension, FS is considered sustainable when there is equity in the distribution of economic value-added i.e., amongst the vulnerable groups, especially in the category of gender, age, and race living in mountainous regions. FS is considered environmentally sustainable by ensuring that the FS activities do have a positive impact on the surrounding environment, say biodiversity, water, soil, etc., (FAO, 2014) as explained in Figure 6.

This paper's proposed method will be using AI in the food system development paradigm and thus will ultimately increase proficiency, helps farmers of all communities to be benefitted and help the mountainous communities thrive to 'produce more from less', and meet the challenges in food systems, India needs the right mix of policies, motivate the private sectors to build more effective value chains, agricultural diversification towards more nutritious food, and the catalytic factor of increasing digitization, IoT and AI will help to build sustainability in FS.

AIR is researching and looking into digital farming using AI. These technologies provide precise location via Global Positioning System (GPS) and record the data which is then useful for forecasting, forewarning, and taking control measures when there are occurrences of natural

disasters. Moreover, we are looking into intelligence in predictive modeling for effective disease or pest management and also investing in capacity building to encourage the wider adoption of new and existing technologies among smallholder farmers to empower and educate them. In the near future, we are also thinking of research and development of much more protected practices like soilless farming systems, polyhouse farming, and vertical farming systems.

We are proposing in this paper that for agriculture to be a long-term sustainable activity it has to go hand in hand with farm incomes and farmer prosperity. Thus, adapting the Carbon capture models to reduce carbon emissions could be a great opportunity for these rural farmers as these models are already in place in the USA and South America (World Bank, 2012). As far as climate change is concerned, our research on adaptation through the use of climate-resilient seeds is making significant changes. Value chain development and marketing platforms that link farms to agricultural output markets play a critical and essential role in determining prices and incentives for the farmers.

We also believe that working towards marketing reforms also needs to be promoted and funded i.e., for the creation of assaying, sorting, and grading infrastructure at the mandis. This will be helpful to reduce the difference in the quality of produce from mandi to the mandi, and also encourage retailers and processors to purchase through e-NAM. Digitalization of value chains and making use of digital platforms will open up more opportunities for well-organized marketing with low market risks, which will be beneficial for both the farmers as well as consumers. Investments in food processing and value addition and also linking the processing with retailing in an organized manner can be used to build efficient and methodical value chains. Investment in solar-powered cold storage will reduce the costs as well as losses of agricultural produce, particularly perishable food products, and this also improves the storage quality. Public-Private Partnerships (PPP) in the supply chain will also help reduce the market risk for farmers and improve price awareness among them.

This paper discusses some of the indigenous farming knowledge as collected through a survey undertaken by one of the AIR team members. The outcome of the survey that we carried out is related to the land preparation/manuring/soil treatment, cropping system, input management, water resource management, and soil, water conservation practices, and is beneficial in making farming practices sustainable around the globe:

- Land preparation for direct-seeded rice after broadcasting is done by using powdered manures mixed with soil and planking. This helps in the mineralization and water holding capacity of the soil.
- Applying a crop rotating system gives good yield without much dependency on irrigation. Rotation cropping systems provide high tolerance to environmental stress and high biomass productivity.

- Input management practices such as composting are done by applying karanji cakes. Waterlogging, Planking, leveling, deep-summer plowing, and the application of karanji cakes help in keeping the land weed-free, controlling pests and termite attacks.
- Water resource management is better done by the construction of Doba structure which is a small rainwater harvesting structure and it is helpful in reducing evaporation and providing irrigation.
- Earthen and stone bunding is useful for the conservation of soil, water, and nutrients and also in the safe storage and sequestration of excess water.
- Crop mulching helps in the conservation of soil moisture during high air temperatures and keeps the soil cool.

This research clearly shows that indigenous people and their knowledge are central to the adaptive changes using available natural resources essential and to face the world's climate change. However, to ensure scientifically credible results merged with traditional knowledge and building capacity, monitoring of the natural resource from time to time is also vital and that is where AI can step in.

Al Solutions for Agriculture

Downpour sustained rice is the principal crop covering 68 percent of Jharkhand. Environmental changes in temperatures, precipitation, barometric carbon dioxide, etc will make rice less nutritious and the yield will also be low. GHG can impact the rice yield efficiency as climatic CO2-prompted changes of the atmosphere and also affect the development pace of harvest plants. Rainless days for even seven days in hilly rice-developing territories can fundamentally decrease rice yields. When salinity increases it results in rice plant stunting, reduced tillering, visibly patchy field growth, reduction in germination, plant height, tillering capacity, and poor root growth. Rice stems have hubs, which break when there is enormous weight because solid breeze/precipitation happens during flooding.





Figure 7 shows how AI can be used in agriculture. It has the potential to benefit the entire agrarian value chain.

- With the help of AI, farmers can analyze weather conditions by using weather forecasting which helps them plan the type of crop that can be grown and when seeds should be sown.
- Al can help farmers to monitor soil and crop health conditions and produce healthy crops with a higher level of productivity.
- Image recognition-based technology applications can identify the nutrient deficiencies in soil including plant pests and diseases by which farmers can also get an idea to use fertilizer which helps to improve harvest quality.
- An AI-equipped drone can capture data from fields and helps the farmer identify pests and bacteria and educating the farmer with timely use of pest control.
- Al applications can help in accurate and controlled farming by providing farmers proper guidance about water management, crop rotation, timely harvesting, type of crop to be grown, optimum planting, pest attacks, nutrition management using an SMS-enabled phone and the Sowing App.
- Al systems use satellite images and compare them with historical data using DL and image processing models to detect which type of insect has landed and then send alerts to farmers to their smartphones so that they can take required precautions.

- Al can effectively be used for differentiating between weeds and crop seedlings using digital imaging. It is one of the most effective non-chemical methods of weed control.
- Al can alert personnel in irrigating agricultural fields and in times of drought. It can monitor and analyze the soil moisture and humidity in the surrounding atmosphere, and mitigate wastage of water by releasing it only when it is required.
- Al can assist in the implementation of proper grain storage techniques by maintaining the proper temperature, pressure, and humidity conditions for various types of crops.

AIR's research is thus aiming to identify policy barriers and provide digital solutions to governing bodies responsible for developing food systems for farmers in the mountain regions of India; thus, aiming to reduce emissions by 15% and improve direct engagement at grass root levels by 25%.

Methodology

AIR's (AI For Rural) activities for building efficient food systems include:

- Having systematic data collection and analysis of data that covers a particular area of interest for the entire Food system (Cognitive Computing).
- Focusing on the design of policymaking by addressing the people/ stakeholders involved in the food system particularly by focusing on the technical and organizational support.
- Supporting the capacities of government bodies to work with business and non-state organizations.
- Collaboration with partners and organizations to learn, adapt and synergize different techniques to achieve common food system goals.

AIR is using Artificial Intelligence through which different intelligence data is collected for the rural and mountainous regions which would then be provided as an information tool for the small-holder farmers for farming, irrigation, and to connect with potential buyers/sellers. We are building an approach of Cognitive computing technology that can help farmers understand and interact with different environments like agriculture, land, and fertilizers to maximize productivity. We have adopted this initiative as it has already resulted in 30 percent higher yield per hectare than average in Andhra Pradesh State.

First of all, we have to capture data points on the ground every day which is a very essential preliminary step for all of the above-mentioned technologies to be used. This will help farmers achieve better yield through better crop selection, resource utilization and improve the quality and accuracy of crops. Moreover, by adopting Precision-farming, we can help educate the farmers about detecting pests, disease in crops, and malnutrition in the field. This will help farmers to optimize the number of pesticides to be used in the field. Furthermore, we are also helping to

educate the farmers in understanding the seasonal forecast models to predict future weather trends. Lastly, it is also important for the farmers to understand and use drone-based AI-enabled cameras to monitor the produce more efficiently by taking real-time images which can then be sent for analysis to identify potential problems and improvements via gamification technique.

Results

AIR is currently working on data collection, analyzing/ tracking, measurement, and reporting. In this paper, we are concentrating on research and development before and after production and on optimizing the harvest of rice production in the state of Jharkhand. The main purpose of this paper is to understand the food system in Jharkhand as our case study and compare them with Andhra Pradesh state as a subject of comparison who is currently leading technology adaptation in the market. During our research, we explored some basic ques like climate change, product, and technology adaptation challenges that exist to adopting new technologies in Jharkhand.

We are exploring and trying to be aware of how farming systems operate, to gain more understanding about the current gaps or how efficient is the food production, and to conscious of how we can invest technology so that we can develop a technique for improvement of challenges that exist to adapting AI in Jharkhand most importantly in the Dumka district. Going forward we are going to continue our research to provide a way for technology adoption and AI readiness in this district and improve collaboration at the grassroots level. Our research should trigger development and improve processes.

Agricultural Production Statistics

States	Agricultural Production: Rice (Thousand Tons)	Year	States	Agricultural Production: Rice (Thousand Tons)
Andhra Pradesh	8,658.900	2020	Manipur	385.500
Arunachal Pradesh	244.700	2020	Meghalaya	303.400
Assam	4,984.600	2020	Mizoram	60
Bihar	6,298.000	2020	Nagaland	363.300
Chhattisgarh	6,774.800	2020	Orissa	8,360.400
Goa	90.400	2020	Punjab	11,779.300

Table 1: Agricultural Production (Rice) in 2020

Gujarat	1,983.100	2020	Rajasthan	480.500
Haryana	4,824.300	2020	Sikkim	16.100
Himachal Pradesh	143.800	2020	Tamil Nadu	7,171.100
Jammu & Kashmir	587.000	2020	Tripura	810.200
Jharkhand	3,012.800	2020	Union Territories	161.6052014
Karnataka	3,634.500	2020	Uttar Pradesh	15,517.900
Kerala	605.600	2020	Uttaranchal	658.400
Madhya Pradesh	4,778.200	2020	West Bengal	15,881.400
Maharashtra	2,897.600	2020		

Table 1 above shows all the Rice producing states of India and the production in the metric thousand tons. We see that Andhra produced 8.65 million metric tons of rice compared to Jharkhand which produced 3.01 million metric tons.



Figure 8: Volume of Rice production across Andhra and Jharkhand from the Financial year 2009 to 2020

From figure 8, we see that in 2020, rice production in Andhra Pradesh was 8.64 million tons. Rice production of Andhra Pradesh increased from 7.45 million tons in 2017 to 8.64 million tons in

2020. Whereas in Jharkhand it decreased from 4.99 million metric tons to 3 million tons in 2020. As much as 63.5 lakh tons of rice have been dispatched from Andhra Pradesh to other rice deficit states by the FCI in the last three years.

One of the major initiatives to achieve this target is to implement modern technologies like AI in the farms and to provide accurate and timely information regarding crops, weather, and pest infection to the farmers. A group of local farmers from the Gudipalli, a small village in the Chittoor district of Andhra Pradesh state will vouch for this. In the past year, these farmers are harvesting the benefits of AI on their farms and increased their yield. Figures 9 and 10 below show the agriculture statistics of Chittoor district and Dumka district respectively before AI was introduced.



Figure 9: Agricultural Production, Area Harvested, and Yield (Rice) in Chittoor District



Figure 10: Agricultural Production, Area Harvested, and Yield (Rice) in Dumka District

Weather Statistics for Farming



Figure 11: Average Rainfall (mm) by month in Santhal Paragana and Chittoor region

Some climate parameters which have a direct influence on Jharkhand agriculture. Precipitation is lowest in Santhal Paragana region in December, with an average of 8 mm and most of the rainfall here falls in July as seen in figure 11.



Figure 12: Average temperature around the year in Santhal Pargana and Chittoor District

At an average temperature of 30.1 °C, May is the hottest month of the year in Santhal Paragana region and January is the coldest month, with temperatures averaging 16.1 °C.



Figure 13: Average daily Sunshine hours per month in Santhal Pargana and Chittoor

Table 2: Weather b	y Month	(Average) in	n Santhal	Pargana	Region
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	Jan	Feb	Mar	Apr	Мау	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temp. °C	16.1	19.9	25.1	29.4	30.1	29.3	27.2	27	26.5	24.6	20.9	17.3
Precipitation /	17	21	19	26	86	201	306	246	223	88	12	8
Rainfail mm (in)	-0.7	-0.8	-0.7	-1	-3.4	-7.9	-12	-9.7	-8.8	-3.5	-0.5	-0.3
Humidity(%)	65%	56%	41%	39%	56%	71%	84%	85%	85%	78%	66%	66%
Rainy days (d)	2	2	2	5	9	15	20	20	16	7	1	1
avg. Sun hours (hours)	9	9.6	10.5	10.3	9.5	8.8	7.3	7	7.2	8.5	9	8.7

Table 3: Weather by Month (Average) in Chittoor Region

	Jan.	Feb.	Mar	Apr	Мау	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temp °C	22.3	24.4	27.2	29.6	30.9	29.2	28.4	27.8	27.3	25.7	23.5	22.1
Precipitation /	9	7	13	21	62	85	83	96	121	153	107	52
Rainfail mm (in)	-0.4	-0.3	-0.5	-0.8	-2.4	-3.3	-3.3	-3.8	-4.8	-6	-4.2	-2
Humidity(%)	68%	58%	53%	55%	51%	57%	58%	62%	65%	73%	76%	74%
Rainy days (d)	2	1	2	3	8	10	9	10	11	13	10	5
avg. Sun hours	7.6	8.8	9.8	10.3	11	10.9	10.2	9.9	9.7	8.3	6.7	6.3

In the Santhal Pargana division, the month with the most daily hours of sunshine is March with an average of 10.51 hours of sunshine as seen in figure 13. With an average of 8.67 hours of sunshine each day, January is the month with the fewest daily hours of sunshine. August is the month with the highest relative humidity (85.03 percent). April is the month with the lowest relative humidity (38.56 percent). July is the month with the most number of rainy days (26.73 days). December is the month with the least number of rainy days (1.27 days).

The major constraint for agriculture in these hilly areas is that more than 80 percent of the arable lands are rainfed. July is the favorable month to plant paddy. But for the last few years, they are being forced to wait till the end of August which is not considered to be a good trend. Delayed monsoon and early exit, both result in poor yield or crop failure. Along with that, water bodies do not get filled up and the water table also does not recharge.

Agriculture Operating Expenses and Revenues- National vs Jharkhand

Jharkhand has a lower bank branch penetration rate than the national average. While the national average is 11.8 bank branches per lakh population, there are 9.16 bank branches per lakh population in Jharkhand.

	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Lead Banks	42.7	40.8	41.1	40.3	37.6	38	38
Other Public Sector Banks	30.8	32.3	32	32.5	32.1	28.5	28.4
Private Sector Banks	6	7.8	8.2	8.6	12.7	13.3	13.3
Scheduled Commercial Banks	79.5	80.9	81.3	81.4	82.4	79.8	79.7
Regional Rural Banks	16.3	15.2	14.8	14.7	13.9	13.9	13.8
Cooperative Bank	4.2	3.9	3.9	3.9	3.7	3.7	3.7
Small Finance Banks	0	0	0	0	0	2.7	2.8
Total	100	100	100	100	100	100	100

Table 4: Proposition of Bank Branches by Type of Banks

Percentage of Bank Branches	Names of Districts				
Above 14 %	Ranchi				
10% to 14%	East Singhbhum				
8% to 10%	Dhanbad,				
5% to 8%	Bokaro, Giridih				
3% to 5%	Deoghar,Dumka, Hazaribagh, Ramgarh, Godda, Palamau, Saraikela, West Singhbhum				
1% to 3%	Chatra, Garhwa, Gumla, Jamtara, Koderma, Pakur, Sahibganj, Simdega, Lohardaga, Latehar, Khunti,				

Table 5: District Wise Proportion of Bank Branches (as of 30.06.2020)

The bank-branches are mostly concentrated in the districts which are highly urbanized and have industrial, mining and commercial centres as shown in Table 5.

Table 6: Deposit an	d Credit of the	Banks as	of 31 st	March of	Each	Financial	Year (Rs. In
Crores)								

Item	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21 (up to Sept.)
Deposits	139956	151224	186178	198114	218101	224364	243119
Credits	65842	70728	81040	85519	95562	96107	94494
C-D of Banks	47.04	46.77	43.53	43.17	43.82	42.84	38.87
C-D Ratio in %, including RIDF and credit as per the place of utilization	61.51	60.61	57.57	60.31	57.33	55.63	50.05

The credit-deposit ratio (C-D ratio) has declined over the years to 55.6 percent in the year 2019-20. It has mostly remained less than the RBI benchmark of 60 percent. The slowdown of the national economy since the last one year and the COVID-19 pandemic of the current financial year have dried up the investment opportunities in the country and in Jharkhand. The PM-KISAN scheme is a Central Sector Scheme with 100 percent funding from the Gol. Under this scheme

an income support of Rs. 6,000/- per year is provided to the small and marginal farmer families having combined land holding of up to 2 hectares.

Agriculture Infrastructure Fund

In order to improve the agricultural infrastructure, the Gol has pledged to give budgetary support for an interest subvention of 3% per annum on loans up to Rs. 2 crores. Jharkhand has a target of distributing Rs. 157 crores into 800 accounts of 3108 branches of the public sector banks, private sector banks, regional rural Banks, and cooperative Banks in the current financial year (2020-21). With the NPJSY (Neelambar Pitambar Jal Sammridhi Yojana) Scheme, the government aims to help the marginal landholders and farmers of the drought-hit region to store an increased volume of 5 lakh crore litres of rain and groundwater every year.

A wide network of all-weather roads is significant not only in increasing rural connectivity but also in faster and sustainable rural development which will be helpful for the farmers. Different schemes for the construction of rural roads in the state are running in collaboration with the Pradhan Mantri Gram Sadak Yojana (PMGSY).

Programs and Initiatives- National vs Jharkhand

In the sphere of agriculture, there are a number of governmental policies and programs that benefit smallholders. Farmers' lives will be made easier by digital marketing platforms like electronic unified agricultural markets (e-NAM), negotiable warehousing, and commodity futures, as well as recent government efforts like the Agriculture Infrastructure Fund (AIF) and Atmanirbhar Bharat (self-reliant India). Agri-marketing reduces transaction costs and food losses by opening up agricultural markets to more competition and allowing farmers to sell what they want, when they want it, without any limits on the sale, stocking, movement, or export of farm produce.

Agriculture and allied industries employ 43 percent of Jharkhand's overall workforce. In the financial year 2021-22, Rs.1200 crores will be available under the Jharkhand Agriculture Loan Waiver Scheme. In each district, one village will be designated as a Birsa village under the Integrated Birsa Village Development Scheme. By creating the Kisan Service Center, a group of farmers will be informed about agricultural amenities such as markets and new technologies as a result of this. The Jharkhand government's Kisan Samridhi Yojana plans to give solar-based irrigation to farmers through this scheme, and Rs 45.83 crore has been set aside in 2021-22 to provide irrigation to a group of farmers using solar-based digging.

Community Managed Sustainable Agriculture (CMSA) was implemented in several blocks with a distinct approach by trained Aajeevika Krishak Mitra (AKMs). The emphasis was on bringing the really poor into the agricultural fold and providing them with a proven set of methods. The Mahila Kisan Sashaktikaran Pariyojana's (MKSP) goal is to empower women in agriculture by improving their involvement in production, as well as to build and sustain agriculture-based livelihoods for rural women.

The Gol is implementing a slew of programs. However, due to a lack of coordination and convergence between state, national and local bodies, there is a mismatch between ground level activity funded from various sources, resulting in inefficiencies in resource utilization and failure to achieve expected results from investments. We believe that connecting farmers to markets through effective policy interventions is a fundamental and urgent necessity for future food and nutritional security. AIR is collaborating with our partners and is actively researching and developing a prototype. During this research phase, we are attempting to improve the end-user product by initiating a feasibility analysis based on which approach best suits a specific region of Jharkhand.

Research Limitations

Food security and nutrition issues require coordinated actions on multiple fronts by all stakeholders at the local, national, regional, and global levels, involving both public and private actors, and spanning multiple fronts such as agriculture, trade, policy, health, the environment, gender norms, education, transportation and infrastructure, and so on. Better agricultural practices, yields, and a qualitative change in farmers' lifestyles are expected as a result of AI. Even though AI has a lot of potential in agriculture, farmers in most parts of the world still need to be educated on how to employ high-tech machine learning solutions.

The acceptance of logical AI solutions is critical to the future of Jharkhand agriculture. While largescale research is currently underway and some applications are now on the market, the industry remains severely underdeveloped. When it comes to tackling realistic challenges faced by farmers and using separate decision-making and predictive solutions to solve them, farming is still at a growing stage. Applications must be strong in order to explore the vast potential of AI in agriculture. Only then it will be able to handle frequent changes in external conditions, ease the real-time decision-making process and make use of an appropriate platform for collecting contextual data in an efficient manner. Another important aspect is the sky-high cost of different cognitive solutions must become more accessible, like in an open-source platform where solutions are more economical and quickly embraced by farmers.

Al systems require a lot of data to train machines and make accurate predictions. Because of the lack of data infrastructure, it will take time to develop a powerful ML model. Jharkhand agriculture is still at an amateur stage when it comes to farmers' decision-making independently and predictions using AI, as they are not yet technology ready.

Conclusions

Al in agriculture not only helps farmers to automate their farming but also shifts to precise cultivation for higher crop yield and better quality while using fewer resources. Agriculture in Jharkhand is known for its low productivity, which has resulted in a high rate of rural poverty. Due to ill–governance, political instability, and corruption, there has been no noticeable improvement

in people's economic conditions or rural infrastructure such as irrigation, water harvesting, rural connectivity and communication, storage and marketing, and so on. The state must invest heavily in rural infrastructure which is a significant roadblock to agricultural development. Farmers should be lent more money by banking and cooperative organizations. Additionally, agriculture must be diversified in order to enhance farm income and employment. Following the implementation of these measures, there will be a greater likelihood of increasing agricultural productivity and production, as well as improving the economic situation of rural people.

From detecting pests to predicting what crops will deliver the best returns, AI can help humanity confront one of its biggest challenges that are feeding an additional 2 billion people by 2052, even as climate change pursues. Farmers can use AI to determine the optimal date to sow crops, precisely allocate resources such as water and fertilizer, identify crop diseases for swifter treatment, and detect and destroy weeds. These activities become smarter over time as a result of machine learning. It can also help farmers forecast the coming year by recommending how much seed to sow based on historical production data, long-term weather forecasts, genetically modified seed information, and commodity pricing predictions, among other inputs. AI solves the scarcity of resources and labor to a large extent and it will be a powerful tool that can help organizations cope with the increasing amount of complexity in modern agriculture It is past time for major corporations to invest in this area.

Acknowledgements

Writing a book is harder than I thought and more rewarding than I could have ever imagined. Firstly, I would like to thank the almighty for giving me strength throughout the process of writing the paper and helping me in all the huddles. A very special thanks to Uday Teki, CEO, and Founder of AI For Rural, my mentor and a friend who brought me on as an intern, as a Research Fellow and then allowed me to rise through the ranks to become what I am now. I've greatly appreciated his counsel during the final stages of completing the manuscript. I owe an enormous debt of gratitude to those Dr. Baktybek Abdrisaev, a Professor at Utah Valley University who gave freely of his time to discuss nuances of the text and pushed me to clarify concepts, explore particular facets of insight work, and explain the rationales for specific recommendations. Finally, none of this would have been possible without my husband, Premkumar. He stood by me during every struggle and all my successes. A lifelong partner makes the journey and destination worthwhile.

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The Contribution of Input-Output Multi-Objective Optimization Model of Sustainable Consumption and Production in Food-Energy-Water Nexus

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Abstract

Food, energy and water are essential for human survival. These resources consume each other thus enhancing security in one resource can reduce security in another resource. Multiobjective optimization approaches have been used to understand the complexity associated with the Food, Energy Water (FEW) Nexus. However most of these approaches focus on either maximizing resource production or minimizing resource consumption in the FEW Nexus but not addressing the two simultaneously. To achieve sustainability of the FEW Nexus sustainable consumption and production of the resources need to be emphasized. In this paper, the Input-Output theory is used to develop a multiobjective optimization model that minimizes resource intensities. Minimizing resource intensities results into minimized consumption and maximized production of resources in the nexus. Using the developed model simulations are carried out to demonstrate its applicability in FEW Nexus. The results show that the model can be used to explore alternative ways of minimizing consumption and maximizing production simultaneously based on the concept of non-dominated solutions.

Keywords: Input-Output Theory, Food-Energy-Water Nexus, Multiobjective Optimization Model, Sustainable Consumption and Production

Introduction

Sustainable consumption and production in Food, Energy and Water nexus has a direct or indirect link in achieving many if not all of the Sustainable Development Goals developed by United Nation. Many countries are concerned about addressing Sustainable Development Goals in the midst of pressures emanating from rapid population growth and climate change. The FEW nexus approach is one that can be used to address the challenges of ever growing demand for food, energy and water. This nexus depicts some complex interactions with hidden feedback connections among food, energy and water resources. The production of a specific resource requires the consumption of one or the two other resources thus playing a big role in determining the demand, supply and availability of the resources in the FEW Nexus. In relation to attaining global sustainability, managing the FEW Nexus has become a big challenge. This is due to the fact that increasing security of one resource may have a negative consequence on another resource. The purpose of this study is to design a multi-objective optimization algorithm based on Input-Output model.

Food, energy, and water resources are crucial for the survival of human beings and the systems involved in the production and consumption of these resources are tightly linked (Yuan and Lo, 2020). The FEW nexus is a term used to depict the complex interactions occurring between food, energy and water systems. The nexus is important in understanding existing interdependencies between the three resources (Itayi, Mohan and Saito, 2021). Climate change, urbanization and population are well known stressors that influence and also are influenced by the FEW nexus (Lange, 2019). Therefore, there is a need to develop adaptation and mitigation strategies to cope with the negative impacts of these stressors. One such strategy is to ensure sustainable consumption and production patterns that is formulated as goal 12 of Sustainable Development Goals(SDGs) (United Nations, 2015).

In FEW nexus water is consumed to produce energy and food, energy is consumed to produce water and food, food is consumed to produce energy. There exist some studies that have discussed measurements relating to the consumption and production in the FEW nexus. For instance, water consumption in energy production (Gerbens-Leenes, Hoekstra and Van der Meer, 2009; Chang *et al.*, 2016), water consumption in food production (Gerbens-Leenes, Mekonnen and Hoekstra, 2013), energy consumption in water production (Mo *et al.*, 2011; Gu *et al.*, 2016), energy consumption in food production (Carlsson-Kanyama, Ekström and Shanahan, 2003; Chang *et al.*, 2016; Gellings and Parmenter, 2016) and food consumption in energy production (Campbell *et al.*, 2008; Zhuang *et al.*, 2011; Bryngelsson and Lindgren, 2013). The weakness of these studies is that they are very general and do not provide specific measurements relating to consumption and production in a specific scale.

Sustainable consumption and production is about using less to produce more. This can be achieved by devising ways of enhancing efficiency in consumption and production of resources in the FEW nexus. Simultaneous minimization of consumption and maximization of production normally leads to high efficiencies. Therefore, a resource use intensity tends to be minimized if the amount of that resource consumed to produce one unit of another resource is reduced. Input-Output Theory is used to address the concept of a resource being consumed to produce another resource (Ebiefung and Kostreva, 1993; Dietzenbacher and Lahr, 2004) .It has been used to compute resource intensities and allocations in FEW nexus (Karnib, 2017a, 2018).

In FEW nexus, minimizing resource consumption and production is a multiobjective optimization task (Okola *et al.*, 2019). Several studies have been done to demonstrate the applicability of multiobjective optimization approaches in FEW nexus. For instance, there is an approach that minimizes costs associated with water, food and energy production as well that of reducing carbon dioxide emission.(Zhang and Vesselinov, 2017). Similarly a framework has been developed to minimize costs associated with consumption of water and energy in order to maximize food production (Karnib, 2017b). A multiobjective optimization approach has also been employed to assist in maximizing the electricity generated through hydropower while minimizing water reduction (Uen *et al.*, 2018). A reliability index is used to quantify each resource demand and supply in FEW nexus. Henceforth, the three indexes are maximized simultaneously (Wicaksono and Kang, 2019). A similar approach maximized a derived WEF nexus index to identify a cropping pattern that is optimized (El-Gafy, Grigg and Waskom, 2017). A nonlinear multiobjective

optimization approach has been proposed to facilitate simultaneous maximization of benefits achieved from groundwater use and to minimize the destruction of resources associated with groundwater production. Therefore, the approach is able to depict the tradeoffs that occur in food, energy and groundwater production (Radmehr, Ghorbani and Ziaei, 2021).

Based on the few highlighted multiobjective optimization approaches, to the best of our knowledge none has emphasized on how to simultaneously minimize the resource consumption intensities in FEW nexus. The main goal of FEW nexus management tools is to identify synergies and tradeoffs that occur during complex interactions between systems linked in and to the nexus thus enhancing strategies used in resource allocations (Borge-Diez, García-Moya and Rosales-Asensio, 2022). Therefore, in this study an approach has been proposed that simultaneously minimize several resource intensities thus assisting the decision maker to identify synergies and trade-offs from the many non-dominated solutions obtained.

Input-Output Theory in Few Nexus

Input-Output Theory

The Input-Output theory specifies interrelationships among various industrial sectors, households, and government agencies in such a way that the output of an industry will appear as input distribution to other industries (Dietzenbacher & MLahr, 2004; Ebiefung & Kostreva, 1993). In this study we apply the Q-Nexus Model that consists of inter resource consumption quantities denoted by Z, final demand quantities denoted by y and the total of the two denoted by x (Karnib, 2017a). Equations 1 is used to formulize the model.

$$Z + y = x \tag{1}$$

The Leontief Input–Output model specifies quantitative relationships between the inputs consumed and the outputs produced in a sector using linear equations. To achieve sustainability in the FEW Nexus, resource consumption and production need to be optimized simultaneously thus conflicting each other.

Resource Consumption and Production

In the FEW Nexus the main resources consuming each other are Food, Energy and Water. These resources can be broken down into specific types of food, energy and water (Karnib, 2017; Wicaksono et al., 2019).

- i. Water resources include Surface water in rivers, lakes and reservoirs (W₁); Groundwater (W₂); Desalinated water from oceans (W₃); Others (W₄).
- ii. Energy resources include Electricity (Wind) (E₁); Electricity (Hydro) (E₂); Biofuels (E₃); Electricity (Fossil Fuels) (E₄); Imported Electricity (E₅); Electricity (Solar) (E₆);

iii. Food resources include Fruits (F1); Roots and Tubers (F2); Cereals (F3); Vegetables (F4);
 Animal Products (F5).

Based on the Input-Output theory and the Q-Nexus Model, the consumption and production of resources in FEW nexus are represented using Table 1.

	Inputs from the producing resources								
Total output of	water(w)	energy(e)	food(f)	demand					
the resources									
water(w)	water-	water-	water-	water-					
	water(ww)	energy(we)	food(wf)	demand(wd)					
energy(e)	energy-	energy-	energy-	energy-					
	water(ew)	energy(ee)	food(ef)	demand(ed)					
food(f)	food-	food-	food-	food-					
	water(fw)	energy(fe)	food(ff)	demand(fd)					

Table 1: Resource Consumption in Producing Another Resource

Table 1 is also formulated using equation 2 to 4

$w = ww + we + wf + wd \tag{2}$	2)
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$$e = ew + ee + ef + ed \tag{3}$$

$$f = fw + fe + ff + fd \tag{4}$$

Objective Functions

The consumption of a resource to produce one unit of another resource is known as resource intensity coefficient. The water-energy, water food, energy-water, energy-food and food-energy intensity coefficients are given using equations 5 to 9. In this case we assume that the amount used to produce water and the amount of food used to produce water is zero. These five equations also represent minimised objective functions.

$$a_{wf} = wf/f \tag{6}$$

$$a_{ew} = ew/w \tag{7}$$

 $a_{ef} = ef/f \tag{9}$

$$a_{fe} = fe/e \tag{10}$$

Simulations

Simulations were facilitated in MATLAB using gamultiobj function. This function allows the components of a Multiobjective Optimisation Problem(MOP) to be combined. These components include objective functions, constraints, lower and upper bounds. Multi-objective optimization approaches can be used to address conflicts in the FEW Nexus because they are known to deal with multiple conflicting real world problems. These approaches provide non-dominated solutions that identify tradeoffs and synergies in FEW Nexus. They have a great potential in solving multi-objective optimization problems. They evolve solutions in each generation thus being able to produce non-dominated solutions which are closer to the Pareto-front.

Simulations are based on the Business As Usual (BAU) resource consumption and production data obtained from the work of (Karnib, 2018) as indicated in Table 2. This data is set to be the values for the lower bound vector. The upper bound vector values are set to either BAU values or to infinity. Therefore, we perform simulations based on the BAU settings for the lower bound and infinity values for upper bound values. The results obtained are used to compare the intensity coefficients for each resource obtained from BAU situations and those obtained after optimization.

Results and Discussion

The results obtained from the simulations demonstrated different ways of attaining sustainable consumption and production. The purpose of the simulation was to demonstrate how consumption and production change when the final demand is changing and resource intensities are minimized simultaneously.

The gamultiobj algorithm generated 78 non-dominated solutions that represented various alternatives of decision making. Only five solutions out of 78 were considered for analysis. For a solution to be selected its resource intensity has to be the one with the lowest value among the 78 solutions generated. For instance, the second row of table 3 indicates the lowest value of water-E1 intensity for a solution where water-energy intensity was the minimum among the 78 solutions. In this scenario the water consumption to produce E1 has increased from 60.000 to 60.055 but the intensity is the same as the one for the BAU scenario that has a value of 0.02502. Water production has also increased from 1900.00 to 1914.39 as indicated in Table 7. If row 5 of table 3 is considered, the lowest water intensity of 0.48494 is for producing F2. The amount of water consumption to produce F2 has increased from BAU value of 171.00 to 171.40 and also the water production has increased from a BAU value of 1900.000 to 1909.060 has shown in Table 7. The same kind of patterns can also be observed with energy consumption in production of water and food as well food consumption in production of energy.

The resource intensities indicated on Table 3 demonstrate alternative options that can be identified by the decision maker in relation to matters of resource consumption and production in FEW nexus. For instance, a sustainable consumption and production pattern can be identified as the one where a resource intensity is reduced, the amount consumed to produce another resource

has a slight increase as compared to BAU value and the total production of the resource has a large increase as compared to the BAU values.

	W1	W2	W3	W4	W5	E1	E2	E3	E4	E5	F1	F2	F3	F4	F5	Y1	Y2	Y3	Y4	Y5	Y6
W1	0	0	0	0	0	40	110	20	0.5	1	120	110	100	180	300	30	1	4	28	0	1
W2	0	0	0	0	0	20	30	0	0.5	1	65	55	60	90	150	154	2	16	146	0	2
W3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	12	4	0	0
W4	0	0	0	0	0	0	1	0	0	0	5	5	5	5	5	0	0	0	0	0	0
W5	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	0	0	0	0	0	0
E1	10	12	10	5	5	0	0	0	0	0	100	60	70	80	150	1000	90	336	470	0	0
E2	80	110	25	2	1	0	0	0	0	0	40	20	30	30	70	1400	160	1071	465	0	0
E3	1	1	2	0	0	0	0	0	0	0	5	5	5	5	5	50	5	30	15	0	0
E4	1	2	1	1	1	0	0	0	0	0	0	0	0	0	2	1	0	4	0	0	0
E5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0
F1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	80	1	10	1	2	50
F2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	228	0	10	2	10	102
F3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	600	1	225	0	2	26
F4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	2	72	2	40	292
F5	0	0	0	0	0	0	0	0	0	160	0	0	0	0	15	2000	200	300	100	60	789

Table 2: Resource Consumption in FEW Nexus

Table 3: Water Intensities in Energy and Food Production

Water	E1	E2	E3	E4	E5	F1	F2	F3	F4	F5
WconBAU	0.02502	0.04024	0.15504	0.07692	0.03333	1.26490	0.48580	0.19393	0.54528	0.12610
WconWEmin	0.02502	0.04058	0.15210	0.27189	0.06329	1.25401	0.48902	0.19420	0.54670	0.12635
WconWFmin	0.02502	0.04063	0.15504	0.30744	0.06282	1.25593	0.48545	0.19393	0.54361	0.12610
WconEWmin	0.02672	0.04151	0.18538	0.13707	0.07561	1.31742	0.49963	0.20427	0.54493	0.12846
WconEFmin	0.02503	0.04070	0.15296	0.30709	0.06406	1.25425	0.48494	0.19409	0.54454	0.12612
WconFEmin	0.03202	0.04607	0.11688	0.14083	0.32543	1.00409	0.52580	0.22663	0.55001	0.13874

Table 4: Water Consumption in Energy Production

Water	E1	E2	E3	E4	E5
WconBAU	60.00000	141.00000	20.00000	1.00000	2.00000
WconWEmin	60.05516	142.36300	20.01827	4.08193	3.79890

WconWFmin	60.00000	142.35046	20.00000	4.07840	3.76944
WconEWmin	64.34103	145.87813	28.03132	4.16328	4.64557
WconEFmin	60.04082	142.65386	20.00340	4.15245	3.84508
WconFEmin	82.62565	168.57551	32.14853	17.38637	22.04613

Table 5: Water Consumption in Food Production

	F1	F2	F3	F4	F5
WconBAU	191.00000	171.00000	166.00000	277.00000	457.00000
WconWEmin	191.52346	172.90412	166.29951	278.86418	458.10222
WconWFmin	191.00000	171.00000	166.00000	277.00391	457.00000
WconEWmin	202.86205	178.91629	176.03808	283.05384	467.28074
WconEFmin	191.20968	171.40068	166.36794	277.24471	457.31991
WconFEmin	212.00274	208.91059	211.07518	310.35453	513.16323

Table 6: Final Demand for Water

	Y1	Y2	Y3	Y4	Y5	Y6
WconBAU	198.00000	3.00000	32.00000	178.00000	0.00000	3.00000
WconWEmin	198.13618	3.43253	33.63530	178.13705	0.00000	3.03897
WconWFmin	198.00000	3.00000	32.00000	178.00000	0.00000	3.00000
WconEWmin	201.46136	14.15120	35.58840	190.03563	0.00000	3.23605
WconEFmin	198.04670	3.21388	32.35969	178.15123	0.00000	3.04971
WconFEmin	219.30587	16.33831	65.74654	211.75857	0.00000	25.22890

Table 7: Water Production

WATER	TOTAL
	PRODUCTION
WconBAU	1900.0000
WconWEmin	1914.3908
WconWFmin	1906.2022
WconEWmin	1999.6830
WconEFmin	1909.0597
WconFEmin	2316.6667

Conclusion

The proposed model has capability to provide various scenarios that can identify synergies and tradeoffs in FEW nexus. Therefore, the non-dominated solutions given by the algorithm are considered as alternatives of optimization of resource consumption and production in the FEW Nexus. These solutions are creating multiple sustainable consumption and production patterns hence enabling policy and decision makers to meet the goal number 12 of SDGs.

From the available literature, it is clear that water consumption has been increasing and yet Over 2 billion people are situated in countries with high level of water stress. Also households' consumption of energy contributes 21% of carbon dioxide emissions. There is evidence showing that degradation of natural resource bases is leading to a decrease in food supply. All such issues can be addressed by formulating policies that are integrative in order to achieve a sustainable consumption and production situation. We therefore need effective tools that can be used to support policy and decision making processes hence avoiding resource wastage or over use. This will mainly address target 12.2 which states that "By 2030, achieve the sustainable management and efficient use of natural resources".

To the best of our knowledge existing approaches are not able to demonstrate ways of how to minimize the resource intensities simultaneously hence they have failed to generate several patterns that depict scenarios that can lead to sustainable consumption and production in FEW nexus. In future a novel Many Objective Optimization algorithm will be developed to handle five or more objectives in an effective way.

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The Universal Health Coverage in Nigeria: The Perception of Public Health Professionals Towards the United Nations Sustainable Development Goal 3

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Abstract

The Ministry of Health have vast potential to facilitate the realization of universal health coverage (UHC) and health system development in Nigeria. Until now, significant gaps exist and threaten its sustainability in many low-income and middle-income countries. Therefore, this study examined nurses' knowledge of UHC for inclusive and sustainable development in healthcare professional practice. This study was a cross-sectional survey. A convenience sample of 125 currently practicing auxiliary, pediatric and critical-care nurses was recruited. Respondents completed a questionnaire which was based on the perception, evaluation, implementation strategies advocated by the WHO Global Forum for nursing officers. Questions covered the government initiative, healthcare financing policy, human resources policy, and the respondents' perception of importance and contribution of nurses in achieving UHC. The results of the study revealed that the effect of nurses' knowledge on UHC on perception of development of healthcare services was significant (β = .38; F= 23.29; p < .00). Also, the contribution of the role of nurses in Nigeria was significant to the improvement in the perception of the universal health services for health workers [β = .39; F = 32.77; p < .00] and the challenges faced by nurses was statistically significant to the decline in achievement recorded in the universal health coverage [β =.42; F = 27.19; p < .00]. In addition, nurses in both clinical practice and management perceived themselves as having more contribution and importance than those in education. They were relatively indifferent to healthcare policy and politics. The study concluded that the survey uncovered a considerable knowledge gap in nurses' knowledge of UHC in healthcare professional practice and shed light on the need for nurses to be more attuned to healthcare policy towards achieving the UN SDGs Goal 3. The educational curriculum for nurses should be strengthened to include studies in public policy and advocacy. Nurses can make a difference through their participation in the development and implementation of UHC in healthcare services.

Keywords: Nurses Knowledge, Universal Health Coverage, Nigerian Healthcare Policy

Introduction

The international community has vast potential to facilitate the realization of universal health coverage (UHC) and health system development. Until now, significant gaps exist and threaten its sustainability in many low-income and middle-income countries (Sachs, 2013). People worldwide still lack access to basic healthcare. In response to this challenge, the United Nations General Assembly passed a resolution unanimously in December 2012. It called on all countries

to plan or pursue the transition of their health systems toward universal coverage (United Nations General Assembly Resolution on Global Health and Foreign Policy, 2013).

The World Health Organization, (2012), sets its objective to ensure that all people obtain the health services they need without suffering financial hardship when paying for them. According to the WHO Director-General, Universal Health Coverage is the single most powerful concept that public health has to offer (Chan, 2013). This consensus has arisen as a mounting body of evidence shows that Universal Health Coverage can deliver significant benefits: for individuals, in terms of access to health services and protection from financial ruin caused by ill health; for countries, in terms of population health and contribution to economic growth (Global Health Strategies, 2013).

However, Nigeria faces challenges that delay the progress toward the attainment of the national government declared goal of universal health coverage. One such challenge is system-wide inequalities resulting from lack of financial protection for the healthcare needs of most Nigerians (Okolo, Nwankwo, Okoli and Obikeze, 2019). This paper aims to synthesize the research evidence on Universal Health Coverage and challenges as it affects health workers perception as well as present policy recommendations in an accessible way to stakeholders and policymakers who might not have a technical background in the plight of health workers.

Universal health coverage (UHC) is defined as the entire spectrum of health services, ranging from health promotion, disease prevention, acute care and treatment, rehabilitation, to palliative care, and it should be financially affordable and geographically accessible to everyone in need (Awojumobi, Remilekun and Okpara, 2017). The definition embraces two key concepts, inclusiveness of the coverage and the sustainable development of the services provided. The former being, how the coverage is representative of the people and how far-reaching are its policies as well as sustaining consistency in effectiveness in accomplishing aims, while the latter portends the how plans, policies are integrated into local and international programmes and what strategies to adopt in other accomplish long and short-term objectives (Awojumobi *et al.*, 2017). The multifaceted quest for sustainable health and development, communities represent a unique and potent resource. Communities that are healthy, empowered, and prosperous are the grassroots drivers of national and regional development (Woodward, Smart, Benavides-Vaello, 2015). Without communities as partners and leaders, all our aspirations for health and development will amount to little more than rhetoric (Iwu, Ekeh and Austin-Evelyn, 2017).

Community health workers who come from the communities they serve, are answerable to these communities, and receive training that is shorter than that required for doctors, nurses or other health professionals represent the essential missing gap, between broad societal yearnings and the communities who both need assistance the most and serve as essential vehicles for progress (Woodward *et al.*, 2015). Few, if any, of our health and development tools match the potential of community health workers to drive gains on multiple fronts. A substantial body of evidence demonstrates that community health workers increase uptake of health services, reduce health inequalities, provide a high quality of services, and improve overall health outcomes (lwu *et al.*, 2017).

Statement of the Problem

The World Health Organization has been advocating UHC over the past few decades to ensure all human beings are able to seek health services and are not deprived of services because of financial hardship (Willmann, 2012). The elderly population is one of the most vulnerable groups that require extra effort to achieve UHC. This is partly because of the loss of gainful employment and partly because of the increased incidence of co-morbidity in this group of people (Willmann, 2012). As expected, demands for health and social care will increase by many folds due to the trending rise in the aging population. Thus, the rights of elderly in accessing healthcare may face unprecedented levels of threat; Nigeria is no exception (Department of Health, 2015).

In Nigeria, the healthcare system, including elderly services, relies on both public sector and private sector. While 88% of the secondary and tertiary healthcare services were provided by the public sector, nearly 70% of the primary healthcare services were provided by the private sector (Chimezie and Faloye, 2014). All Nigeria citizens are eligible to seek medical services from the public sector at an extremely low fee. This fee may also be waived if the person covered by the comprehensive social security scheme (Chimezie and Faloye, 2014).

The development of the nursing profession in Nigeria is considered relatively more mature than in many African countries, yet the level of nurses' participation in politics was reported to be low (Tajudeen, Ifeanyi and Owoeye, 2015). Often, nurses were perceived to be apathetic to political decisions, even if they were healthcare related (Nwanfor, Ogoribuno and Nza, 2018). Heavy workloads, a sense of powerlessness, gender bias, lack of understanding of the political and policy making process, and ethical conflicts between professional and political values may account for this. Nurses, as one of the major healthcare providers, are the key members in the provision of quality healthcare services, and advocate for health choices and health policies (Tajudeen *et al*, 2015). It is important for them to be knowledgeable of the implementation strategies for UHC, even if they do not fully understand.

Healthcare services for impoverished in Nigeria are far from adequate, despite many new initiatives have been implemented (Nwanfor *et al.*, 2018). Many institutions, such as day centers, skilled nursing facilities and infirmaries want to support the initiatives; however, they cannot find enough nurses to do so. The goal of achieving UHC for public healthcare services is moving farther away. The situation does not appear to have any impact on nurses. This is rather unusual, as nurses have been very devoted to vulnerable people in Nigeria (Kayode and Ossai, 2018). Hence, this paper focuses on fundamental challenges of health workers in the purview of the UHC.

Now, a vast proportion of health policy debate is focused on realizing the 2030 Sustainable Development Agenda, a milestone which places specific importance on universal health coverage (UHC) a concept which supports a collective credence that all people should have access to the health services they need without risk of financial ruin or impoverishment (World Health Organization,2012). However, considering the present inequalities within countries, achieving UHC in Africa and particularly Nigeria, will require inclusive participation between health systems

and the citizens across primary, secondary, and tertiary levels (Smith, 2004; Adongo, Phillips and Aikins, 2014). As a result, community health system performance has become increasingly relevant to both high-income countries and low-income and middle-income countries (London, 2008).

One of the fundamental problems associated with UHC is healthcare consolidation, funding, and investment (Adongo *et al.*, 2014). While the case for investment in health is clear, it is less straightforward to determine whether investments in health are more beneficial than those in areas such as education or infrastructure. Also, the strength of the case for investing in health varies among countries. The return on investment is likely to be highest for emerging economies; they can obtain significant improvements in health outcomes (e.g., life expectancy) through modest increases in health expenditure. However, higher income countries might already be at a level of expenditure where the marginal return, in economic and health terms, for increased investment would be relatively small (Adongo *et al.*, 2014).

Where policymakers have decided to make transformative investments in health, there are further choices to be made, such as how to allocate resources between improving health services and addressing the social determinants of health. Improving water quality and sanitation, or funding girls' education, may be as effective at improving health outcomes as spending on health services. However, given that strengthening health systems is vital to improving health outcomes, Universal Health Coverage is a highly effective way for countries to deliver significant health, economic and political benefits.

Review of Related Literature

The empirical evidence from various regions mostly supports the theoretical expectations described above. Several evaluations of a national health insurance program in Nigeria, for example, find positive impacts on health care utilization. Nwanfor, Ogoribuno and Nza, (2018) for example measure the subsidized regime component of the program finding the intervention to greatly increase utilization of medical care among poor and previously uninsured individuals Giedion *et al.* (2017).

In a recent study, King *et al.* (2019) examine the impact of the randomly assigned Mexican universal health insurance program Seguro Popular. The phased rollout of the program provides an experimental design for a study of a program aimed at reaching 50 million uninsured Mexicans. This study, however, shows Seguro Popular to have no significant impact on the use of medical services but it is important to note that the study is based on a time span of only 10 months. Galarraga *et al.* (2010) found that in Seguro Popular there was a reduction of catastrophic health expenditures of 49 percent for the experimental evaluation database (the same used by King *et al.* but using a different method) and 54 percent for the whole country based on a DHS-like survey. In addition, the authors found a reduction of out-of-pocket health expenditures for most types of services.

Findings in Asia are mostly positive. Chen *et al.* (2007) find that one year after the establishment of Taiwan's National Health Insurance scheme, previously uninsured elderly people increased their use of outpatient care by nearly 28 percent. Previously insured elderly people increased their use by over 13 percent leaving a chance of nearly 15 percent which can be solely attributed to the National Health Insurance scheme. In a study of a national rural health insurance scheme in China, Wagstaff *et al.* (2017) find that the scheme increased utilization of both inpatient and outpatient care by 20-30 percent but that the scheme had no impact on utilization among the poor. Yip *et al.* 2008) find that the China health insurance program increased utilization by 70 percent. Wagstaff and Moreno-Serra (2017) investigate the impact of the introduction of social health insurance in 14 countries in Central and Eastern Europe and Central Asia and find an increase in acute in-patient admissions.

There are few impact evaluations of health insurance in African countries and those that do exist demonstrate a weaker methodology than the articles reviewed above. One example is Smith and Sulzbach (2018) which examines the impact of health insurance in three African countries. The authors find a correlation between health insurance and use of maternal health services but highlight that the inclusion of maternal health care in the benefits package of the insurance is key. In Jutting (2003), the author finds in a study of community-based health insurance in Senegal an increase in utilization of hospitalization services but a failure of the program to address the needs of the poorest of the poor. In addition to impacts on health care utilization, health insurance is expected to provide financial protection because it reduces the financial risk associated with falling ill. Financial risk in the absence of health insurance is equal to the out-of-pocket expenditures because of illness.

Additional financial risk includes lost income due to the inability to work. There is little rigorous empirical evidence measuring the impact of health insurance in its ability to provide financial protection. The existing literature examines the impact of health insurance on out-of-pocket expenditures for health care measured in either absolute or in terms relative to income (expenditures are labeled catastrophic if they exceed a certain threshold). King *et al.* (2009) in their study of the Mexican universal health insurance program Seguro Popular find reductions in the proportion of households that suffer from catastrophic expenditures and a reduction in out-of-pocket expenditures for in- and out-patient medical care (though no effect on spending for medication and medical devices).

Wagstaff *et al.* (2007) find no impact on out-of-pocket health expenditures in rural China which contrasts with Wagstaff and Yu (2007) who find reduced out-of-pocket. Achieving universal health coverage in Nigeria one state at a time may involve payments, lower incidence of catastrophic spending and less impoverishment due to health expenditures. By contrast, in a later study, Wagstaff and Lindelow (2018) find health insurance in rural China to increase the risk of high and catastrophic spending. The authors define high spending as spending that exceeds a threshold of local average income and catastrophic spending is defined as exceeding a certain percentage of the household's own per capita income. This finding contradicts the hypothesis that health insurance always will reduce financial risk.

The above mentioned Wagstaff and Moreno-Serra (2017) study of Central and Eastern Europe and Central Asia finds an increase in government spending per capita on health but not in private health spending, while a switch to fee-for-service does increase private health spending. They find negative effects of social health insurance on overall employment levels but positive effects on average gross wages in the informal sector. Since it is difficult to measure the impact of improvements in quality per se, and because few insurance interventions explicitly address the supply-side, the literature is unclear about the separate impact of quality improvements of the supply of care versus making health insurance available and affordable.

Theoretical Explanation

Public-Private Partnership Community-Based Model

The necessary elements to ensure a functioning health system are: financing (risk pools and prepayment); administrative systems; health care providers such as clinics and hospitals, medication and laboratories; and the client/patient relationship. The demand (financing) side and the supply (delivery) side should be aligned and managed to deliver care to the patient, who will therefore be willing to prepay to ensure the availability of quality services when needed. An alternative model is a public-private partnership community-based health insurance model (PPP-CBHI). This model has the potential to contribute to the achievement of UHC by addressing many of the constraints described in the previous section. The PPP-CBHI model is based on three main pillars:

- 1. Building on existing local public and private institutions and informal networks;
- 2. Leveraging existing capital; and
- 3. Empowering local clients and communities.

Achieving universal health coverage in nigeria one state at a time. In this model, donor funds can be used to catalyze the development of a more sustainable health system by stimulating investment and risk pooling mechanisms. In this way both the demand and supply-side are addressed. In developed countries, public institutions facilitate economic exchange in society by reducing risk and moral hazard. Public and social goods like health care, water, sanitation and education are effectively organized by the state through public or semi-public institutions. However, in low and middle-income countries like Nigeria the limited functioning of the state and its institutions hampers economic development and the rendering of public goods and services. Informal institutions often take the place of public institutions and transactions within those institutions are commonly enforced by social pressure and other social norms. Interventions therefore, that build on existing local and often informal institutions for which there may be greater trust, are more likely to succeed.

This can be achieved by, for example, leveraging social capital of communities and their local leaders, and their existing ties with private providers. In this model, groups such as microcredit

members, farmers, or market women are targeted to build on the existing social capital present in the group. Also, contributing to the strengthening of formal institutions (e.g. quality standards/accreditation, investment funds for social infrastructure), through involvement of the private sector in the delivery of essential public, semi-public and social goods, is a logical step.

Leveraging Existing Capital

In many developing countries, the private sector is an important provider of health care, including for its poor who pay for these private services largely out-of-pocket. Increasingly, many of the facilitating functions for healthcare information, quality certification, technology support, human resources are also provided by the private sector. This makes the private sector an important partner to reach the primary beneficiaries, namely, low-income groups, and facilitate systemic change in a bottom-up approach.

Harnessing the out-of-pocket expenditures into prepaid systems rather than crowding them out with public health funding is another important element of this model. Another important element is the leveraging of donor funding to mobilize private capital.

Empowering Clients and Local Communities

Ownership by and empowerment of clients and the communities they belong to is of crucial importance for the approach to succeed. A client-oriented approach requires knowledge about what clients want and need and what they can afford and are willing to (pre) pay. It implies the importance of delivering good quality care to the clients/patients, which requires building a strong health care supply chain: without good quality supply the willingness to prepay is likely to be low (Ogungbe and Eche-Gilbert, 2019).

How the Model Works

Based on these three main pillars, a multi-pronged approach for an alternative insurance model was developed by the Health Insurance Fund (HIF), a Dutch foundation set up in 2005 to increase access to quality basic health care and to provide financial protection through the provision of private community-based health insurance to low-income Africans. On the demand side, existing private resources for health care are used more efficiently to realize solidarity (based on health risk) and protect scheme members from unexpected financial shocks due to ill health. At the same time, the health insurance schemes generate financial resources to build up an efficient supply chain and empower members to insist on high-quality care, creating a snowball effect. People who can pay are induced to pay into risk pools, thereby creating stable health care demand. Improved efficiency in the supply chain lowers costs and raises quality, increasing peoples' willingness to pay. As more people buy health insurance, schemes grow, resulting in larger cross-subsidization, which enhances equity.

Through volume effects, the costs and premiums can be further reduced. These schemes do not compete with government programs but complement them. Beneficiaries are involved in

determining who has access to the schemes, the design of the benefits package, the level of premiums, and the costs to be covered.

The supply side is strengthened through facilitating private investments, both debt and equity capital. Supply-chain upgrading is undertaken through quality-improvement programs with rigorous monitoring and control, preferably in cooperation with international accreditation organizations. Where regulatory capacity of the government is weak, enforcement of quality standards to ensure adequate delivery of care can be a task for the private sector. Output-based contractual agreements provide a good opportunity to do this while achieving universal health coverage in Nigeria is possible in one state at a time (Ogungbe and Eche-Gilbert, 2019).

Donor funds are used to subsidize the community-based health insurance schemes' premiums. Disease-specific donor programs such as for HIV/AIDS, malaria, tuberculosis support the insurance schemes through a risk-equalization arrangement built into the programs. These long-term donor commitments are made with the solvency of the insurance funds serving as collateral, which lowers the investment risk and makes investments in the health care supply chain feasible. Limited donor funding is also used to upgrade the supply chain. Finally, donor funding is used as a lever to mobilize additional private capital to scale up the interventions.

The Health Insurance Fund and PPP-CBHI Model in Nigeria

In 2006, Health Insurance Fund (HIF) received a £100 million grant from the Dutch Ministry of Foreign Affairs to launch, together with its implementing partner, community-based insurance programs in four African countries, including Nigeria. In this public-private partnership model of community-based health insurance, donor funds are linked to African health maintenance organizations (HMOs), insurance companies, or third party administrators. These organizations are responsible for the execution of HIF's insurance programs and for contracting a network of public and private providers where scheme members can get their health services. Payment of insurers and providers is performance-based, measured as the medical care delivered and the number of enrollees. Insurers' prices and profit margins are contractually fixed.

The insurance package consists of primary and limited secondary care, including treatment for malaria, testing for HIV/Aids and TB. The programs are always complementary to regular public sector health programs. The programs create stable healthcare demand by subsidizing insurance premiums for target groups of African workers that enroll with the HMOs.

The program covers groups with at least some income, who must pay part of the (reduced) premium themselves. HIF's resources are also used to upgrade medical and administrative capacity of the insurers and health providers contracted under the program. Quality and efficiency are further pursued by strictly enforcing medical and administrative standards through independent audits. This reinforces the output-based approach: payment only takes place if the patient has received treatment that meets the agreed quality requirements. The quality improvement activities of health care providers under the HIF program are formalized and put under the aegis of an independent quality improvement and evaluation body called SafeCare.

This organization acts as the custodian of internationally recognized standards covering the spectrum of basic health care for providers in resource-restricted countries.

To date, HIF programs have been established for market women and farmers in Lagos, Nigeria, coffee growers in Tanzania and for groups of dairy and tea farmers in Kenya. Currently, a total of 121,000 people are enrolled. The expansion of the program to other African countries is currently under discussion.

Conceptual Review

This study reviewed several literature concerning to the following areas such as; identifying and categorizing prospects and challenges for health workers especially nurse's perception towards Universal Health Coverage within the Nigerian polity as well as theoretical framework that explains specific areas of this study. The health and well-being of Africans are fundamental to Africa's future. To ensure a healthier, more secure future, Africa has embarked on a historic effort to lay the foundation for sustainable health and development for all.

Agenda envisages a 50-year effort to galvanize a socioeconomic transformation across the continent. A key element of this transformation involves harnessing the "demographic dividend" to drive progress towards increased economic growth, social development and shared prosperity. The African Union's 'Africa Health Strategy' and the 'Catalytic Framework to End AIDS, TB and Eliminate Malaria by 2030' provide key goals, strategies and milestones for the journey towards a healthy and prosperous Africa. Making optimal use of technology, including digital communications platforms where feasible, will play a pivotal role in achieving these aims.

In this multifaceted quest for sustainable health and development, communities represent a unique and potent resource. Communities that are healthy, empowered and prosperous are the grassroots drivers of national and regional development. Without communities as partners and leaders, all of our aspirations for health and development will amount to little more than rhetoric. Community health workers who come from the communities they serve, are answerable to these communities, and receive training that is shorter than that required for doctors, nurses or other health professionals represent the essential "missing link" between broad societal yearnings and the communities who both need assistance the most and serve as essential vehicles for progress. Few, if any, of our health and development tools match the potential of community health workers to drive gains on multiple fronts (Chizaram and Uchenna, 2017).

A substantial body of evidence demonstrates that community health workers increase uptake of health services, reduce health inequalities, provide a high quality of services and improve overall health outcomes (Chizaram and Uchenna, 2017). Community health worker programmes also represent good jobs, bolster national and local economies and increase productivity by improving health and well-being. Investments in community health workers will also enable Africa to turn the projected near-doubling in the youth population through 2050 from a potentially perilous "youth bulge" into a dynamic "demographic dividend" that drives economic growth and improves living standards. Indeed, investments in community health workers represent an ideal opportunity to

tackle one of the most vexing problems in Africa, the perilously high levels of unemployment among young people.

Impacts of Health Insurance in Low and Middle-Income Countries

A broad range of risk-pooling mechanisms or insurance schemes are increasingly being utilized across the developing world to increase access and reduce the financial burden of health. The number of evaluations of such efforts is growing and while findings are mixed, the overall findings on impacts are encouraging. In theory, we expect health insurance to contribute to achievement of UHC because it increases access and utilization by lowering the price of health care. Individuals will have better health if they utilize preventive and curative health care when needed and in a timely manner (UNDP, 2011).

Several studies that evaluate the impacts of programs ranging from NHI and SHI to CBHI on health care utilization and financial protection (Usoroh, 2012; Sachs, 2013). Broader definition of UHC given the lack of agreement on the specific systems that might be utilized to achieve it and because we argue that a national system may not be the only answer to achieving universal coverage. A systematic review of the impacts of health insurance on health status in low and middle-income countries can be found in Giedion *et al.* (2013).

Nigeria Strives to Achieve Universal Health Coverage

Nigeria, with its population of around 162.5 million and a population growth rate of 2.5 percent, is the most populous country in Africa and the 8th most populous country in world (Iwu, *et al.*, 2017). The country's tumultuous history is reflected in its abundance of states beginning with only three states at the time of Nigeria's independence from the United Kingdom in 1960 and now with 36 states and the Federal Capital Territory (FCT), where the capital Abuja is located. This highlights the potential challenges of managing such a heterogeneous country.

Nigeria is ranked as one of the fastest growing economies in the world with a growth rate of 6.4 percent in 2007 and 7.4 percent in 2011 (Dutta and Hongoro, 2013). Nigeria's GDP per capita in PPP adjusted dollars is \$1,500 according to World Bank estimates from 2011. One of the main issues facing the country is balancing oil sector revenues and government spending. Over the last few years, the accrued oil revenues have not led to improvements in the welfare of most of the population (Dutta and Hongoro, 2013).

Poverty incidence has varied but remained high over the past decade. In 2004, the poverty rate was 54.4 percent., it rose to 62.6 percent in 2010 and dropped back down to 54.4 percent in 2011 (Kayode and Ossai, 2018). There are great regional disparities, reflected in a contrast between rural areas with a poverty rate of 69.0 percent and 51.2 percent in the urban sector. The poorest zones of the country are those in the North while the South East zone has the lowest incidence of poverty. Inequality, as measured by the Gini coefficient, rose steadily since 1985, save for a slight decline in 1992 (Kramer, Osagbemi, Tanović and Gustafsson-Wright, 2013).

As of 2011, the total population inequality is back at the only slightly better 1992-levels with a Gini coefficient of 0.397. Human development indicators are staggeringly low considering the country's GDP per capita. Nigeria ranks 156th out of 173 countries with data on the Human Development Index (HDI) (Okolo *et al.*, 2019).

The State of Health in Nigeria

Nigeria's health indicators have either stagnated or worsened during the past decade despite the federal government's efforts to improve healthcare delivery. Life expectancy at 52 years is below the African average, while the numbers on child mortality are astounding partly because of the country's size. Annually, one million Nigerian children die before the age of five due mostly to neonatal causes followed by malaria and pneumonia (Smith and Sulzbach, 2018).

Maternal mortality is 630 per 100,000 live births which is comparable to low-income countries such as Lesotho and Cameroon. An estimated 3.3 million Nigerians are infected with HIV and access to prevention, care and treatment is minimal. Nigeria also continues to combat the double burden of both communicable and non-communicable diseases (Smith and Sulzbach, 2018).

Policymakers and political leaders face tough choices and trade-offs when considering where to allocate the limited resources at their disposal. Competing priorities make such decisions very hard, and political dynamics often have a bigger role in determining the answers than evidence-based evaluations of value for money. In this opening chapter we seek to briefly make the case for investment in UHC (Giedion and Díaz, 2010).

The benefits of investing in health are significant and not limited to improving the health of the population: there can be significant economic returns and social benefits. A recent report by the Lancet Commission on Investing in Health lays out the channels by which health improvements have a direct impact on GDP: productivity (healthy people are more productive and less likely to take sick days); education (healthier children are more likely to go to school); investment (people are more likely to save when life expectancy is longer); access to natural resources (can be affected positively by a reduced risk from endemic diseases); temporary impact on ratio of working-age to dependent people (Tajudeen, Ifeanyi and Owoeye, 2015). It showed that reductions in mortality accounted for about 11 percent of recent economic growth in low- and middle-income countries, or even 24 percent of growth if the value of added life years is used to calculate a country's 'full income' (Smith and Sulzbach, 2018).

While the case for investment in health is clear, it is less straightforward to determine whether investments in health are more beneficial than those in areas such as education or infrastructure. Also, the strength of the case for investing in health varies among countries (Gertler and Gruber, 2002). The return on investment is likely to be highest for emerging economies: they can obtain significant improvements in health outcomes (e.g., life expectancy) through modest increases in health expenditure (Takian and Akbari-Sari, 2016). However, higher income countries might already be at a level of expenditure where the marginal return, in economic and health terms, for

increased investment would be relatively small (Preker, Lindner, Chernichovsky and Schellekens, 2013).

Where policymakers have decided to make transformative investments in health, there are further choices to be made, such as how to allocate resources between improving health services and addressing the social determinants of health (Davig, Eric and Leeper, 2018). Improving water quality and sanitation, or funding girls' education, may be as effective at improving health outcomes as spending on health services (Gerdtham and Magnus, 2020). However, given that strengthening health systems is vital to improving health outcomes, UHC is a highly effective way for countries to deliver significant health, economic and political benefits:

- a. Health: There is now significant evidence that UHC brings health improvements to the population of countries that implement it. Researchers using data from 153 countries concluded in The Lancet that "broader health coverage generally leads to better access to necessary care and improved population health, with the largest gains accruing to poorer people".8 A recent review study9 found that UHC reforms have been a powerful driver for improving women's health in a number of low- and middle-income countries including Afghanistan, Mexico, Rwanda and Thailand.
- b. Economic: Apart from delivering the aforementioned economic benefits deriving from improved health, UHC can be an effective policy to reduce inequalities and poverty levels. The financial protection it provides can have further beneficial effects, for example helping reduce excessively high savings rates in families concerned about unpredictable healthcare costs as has been the case in China. UHC systems can help generate and support significant employment in the health and life sciences sectors.
- c. Political: The debate around the Affordable Care Act in the United States shows that the politics of UHC can be highly controversial. However, introducing UHC in a country with limited healthcare coverage for the majority of the population can provide significant benefits for politicians. The most recent example of this has been President Joko Widodo (Jokowi) of Indonesia, whose focus on improving healthcare coverage has been an important driver in his political rise from city mayor, to Governor of Jakarta, to head of state. Politicians have also recognized the power of UHC to maintain social order and reduce the scope for conflict. Reporting on the decision of the Chinese Government to launch massive public health reforms in 2009, the then Minister of Health Chen Zhu said that the government's primary motivation was to ensure a harmonious society (Gerdtham & Magnus, 2020).

Nigeria's Health System

Nigeria has a federally funded National Health Insurance Scheme (NHIS), designed to facilitate fair financing of health care costs through risk pooling and cost-sharing arrangements for individuals. Since its launch in 2005 the scheme claims to have issued 5 million identity cards, covering about 3 percent of the population (Nyandekwe, Nzeribe and Kakoma, 2018). Under the

National Health Insurance Act 2008, the national health insurance started a Rural Community-Based Social Health Insurance Program (RCSHIP) in 2012. The majority of the enrollees, however, are individuals working in the formal sector and the community scheme still leaves large gaps among the poor and informally employed (Nyandekwe *et al.*, 2018).

Several proposals are currently in the works to expand the reach of NHIS. One such proposal is to make registration mandatory for federal government employees. The creation of a "health fund" collecting an earmarked "health tax" of 2 percent on the value of luxury goods was proposed (Opatunde & Zachariah, 2019). This fund would be used for the health insurance of specified groups of Nigerian citizens, including: children under five, physically challenged or disabled individuals, senior citizens above 65, prison inmates, pregnant women requiring maternity care, and indigent persons. At a broader level, the National Health Bill which was first proposed in 2006 to improve its poor health sector by allocating at least 2 percent of the federal government's revenue to the health sector is still not signed into law (Opatunde & Zachariah, 2019).

Constraints to Achieving UHC in Nigeria

According to Omehi and Azubuike, (2018) the constraints to achieving UHC in Nigeria are numerous and complex. Factors limiting Nigeria's health outcomes are both demand and supplyside including inadequate financing, weak governance and enforcement, inadequate infrastructure and poor service quality, weak governance and enforcement, household poverty and insufficient risk pooling.

1. Inadequate Government Financing for Health

Dehinde & Osagie (2019) postulated that there are four main sources of public funding for the public (non-federal) health sector: state governments, local governments, direct allocations from the federal government, and private individuals and organizations, including non-governmental organizations and international donors in some states. The federal government and some state governments have increased funding to public health care (PHC) over the past decade, with a dramatic increase between 2005 and 2007 (Dehinde & Osagie, 2019).

Achieving universal health coverage in Nigeria one state at a time 7 increase in health sector allocations jumped from 31.4 percent to 86.2 percent. Nonetheless, Nigeria spends a mere 5.3 percent of its GDP,) or \$139 (PPP) per capita on health care. This is extremely low, in particular when compared to other African countries such as Burkina Faso (6.7 percent) and the Democratic Republic of Congo (7.9 percent), which have considerably lower GDP per capita (Dehinde & Osagie, 2019).

The government contributes only 36.7 percent of the country's total spending on health. In order to achieve effective access and financial protection, the government must begin by making a more serious commitment to spend on health. The absence of institutionalized National Health Accounts (NHA), however, contributes to the challenge of reassessing health spending in the country. Finally, low levels of external health financing reflect an unwillingness to invest in the

country. Just 9.2 percent of spending is donor funded, which is very low compared to, for example, Ghana with 16.9 percent, which has a comparable GDP per capita (Alhassan & Okonji, 2019).

Weak Governance and Enforcement

The existing legislative structure for budget allocations to social sectors as well as weak governance and institutions leads to inefficient spending and lack of trust in the system. State governments in Nigeria have substantial autonomy and exercise considerable authority over the allocation and utilization of their resources. This arrangement constrains the leverage that the federal government has over state and local governments in terms of getting them to invest in the health sector (Alli and Uwaji, 2018).

Therefore, top-down approaches continue to fail to produce improvements in access, financial protection, and health indicators. In addition, the public system lacks transparency and enforcement, making it subject to corruption and lending inadequate medical and administrative capacity to produce services efficiently and of adequate quality. A weak institutional framework leads to high uncertainty and risk and thereby low levels of trust which reduces the willingness of individuals to invest. Therefore, the willingness to prepay for health care remains low (Alli & Uwaji, 2018).

Inadequate Health Infrastructure and Poor Service Quality

Low government spending combined with weak institutions and lack of enforcement lead to inadequate health infrastructure and poor service quality. Due to the unwillingness to invest in health or prepay for health care, predictable revenue flow is unavailable for health providers to improve the supply chain leaving much of the country's health infrastructure in a dismal state (Tangcharoensathien, Oyeneye & Jafarudeen, 2019). Many health facilities lack access to clean water and a reliable supply of electricity, face shortages of medical equipment, and are missing necessary medications or blood to treat their patients.

In addition, there is a deficiency in qualified health professionals in particular in poor communities (Ogungbe & Eche-Gilbert, 2019). Large disparities exist between urban and rural areas and between states due to the variation in remuneration packages for health professionals across states and between federal and state level, health professionals gravitate to better paying federal facilities and states (Ogungbe & Eche-Gilbert, 2019). Private providers mainly operate in urban settings where income levels are the highest. This situation results in a lack of qualified and competent health professionals for individuals who live in poor rural areas that tend to bear a greater disease burden (Tangcharoensathien *et al.*, 2019).

Gap in Literature

The essence of this study is to fill the existing gap in knowledge where focus on the Nigeria's quest towards achieving the Universal Health Coverage in line with Goal 3 of the United Nations

Development Goals is being challenged by pragmatic policy focus because of lack of knowledge of the UHC for inclusive and sustainable development in healthcare professional practice.

Methodology

A cross-sectional survey was conducted in June and July of 2021. The study made use of primary source of data collection. Through the administration of pencil-paper questionnaire to elicit responses from nurses. A list of potential respondents was generated from a pool of nurses who had experience interacting with the researcher and her research team. The respondents were informed about the purpose of the study and how the details of the study would help improve nursing practice.

This research considered the eligibility of the nurses who volunteered to participate in the study. Having obtained their consent to participate, the research team continued the exercise by giving out questionnaires to the (nurses) respondents electronically. Phone calls were sent to them two and four weeks after the initial distribution of the questionnaire. Names were not collected, to ensure anonymity of the respondents.

Data analysis was conducted using the version 20 of the Statistical Package for Social Sciences, version 20 and to ensure ecological validity, the research team developed a demographic profile section and 4 questions initially based on the implementation biographical information as recommended by the WHO Global Forum for the Governmental Chief Nursing Officers and Midwives (GCNOMs).

Apart from the demographic profile, there were two parts in the final version of the questionnaire, namely, knowledge of inclusiveness of UHC and the perceived contribution to sustainable development of UHC. Inclusiveness of UHC was composed of the government initiative (Q3), healthcare insurance and financing policy (Q1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12), and human resources policy (Q13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26 and 27. Respondents were asked to indicate how they evaluate the importance of contribution of Nurses in Nigeria to their level of knowledge of UHC. For sustainable development of UHC, respondents were asked to rate their perceived contribution (Q28, 29, 30, 31, 32, 33, 34, 35, and 36) and perceived importance of nurses (Q37, 38 and 39, 40, 41, 42, 43 and 44).

Split half reliability was performed using Spearman's coefficient which was satisfactory at 0.881. With the unique function of the Likert-type questionnaire system, the respondents' answers were automatically compiled in a table format. Descriptive and inferential statistics were then computed and a comparison was performed by years of experience, job title, nature of one's role, and their qualifications.

Data Interpretation

The study considered the analysis of data generated from the research study in relation to the responses obtained through questionnaire administration. A total of one hundred and thirty-one

(131) questionnaires were initially distributed, however, only one hundred and twenty-five (125) were retrieved. Three (3) healthcare facilities were engaged for this study namely; Federal Medical Centre, Airport Road, Jabi Federal Capital Territory, Abuja and Save-A-Life Mission Hospital Stadium Road, Port-Harcourt, Rivers State, Nigeria, as well as, New General Central Hospital GRA, Asaba, Delta State, Nigeria. Respondents (Nurses) at the Federal Medical Centre, Airport Road, Jabi FCT, Abuja were sixty-nine, 69 making a total of 55%, of the entire population of the study. Nurses from the Save-A-Life Mission Hospital Stadium Road, Port-Harcourt, Rivers State Nigeria were forty-one 41 making a total of 33% respondents and the nurses who participated in this study, from New General Central Hospital GRA, Asaba, Delta State, Nigeria were fifteen 15 making a total of just 12%. The responses or data retrieved from the questionnaire administration formed the basis of the following results.

Table 3.1: Showing the Categories of Nurses (Respondents) from the 3 Hospitals that Participated in the Study

s/n	Categories of Nurses	Frequency	Percent	Valid	Cumulative
				Percent	Percent
1.	Auxiliary Nurses	56	44.8	45.0	45.0
2.	Pediatric Nurses	41	32.8	33.0	33.0
3.	Critical Care Nursing	28	22.4	22.0	22.0
	Total	125	100	100	100

Source: Field Analysis, (2021).

From the result 3.1., categories of Nurses that participated in the study from the three hospitals used in the study suggest that auxiliary nurses had the highest population with 56(44%), closely followed by Pediatric Nurses who were 41(32.8%) of the entire population and the least category were critical care nurses who were 28(22.4%) of the entire population.

Table 3.2: Showing the Age Distribution Information of Nurses from the 3 Hospitals thatParticipated in the Hospital

Age Range	Mean	Standard	Frequency	Percent	Valid	Cumulative
		Deviation			Percent	Percent
	34.56	6.37				
17-30			66	52.8	53.0	53.0
31-50			36	28.8	29.0	29.0
50above			23	18.4	18.0	18.0

Source: Field Analysis, (2021).

From the result Table 3.2., revealed that age distribution of nurses with an average age of 34.56 and the majority of respondents where within the age bracket of 17-30 (53%), closely followed

respondents within the age bracket of 31-50 (29%), and age bracket of 51 and above was 18.2% of the entire population of the study. Thus it can be inferred that the respondents of the study were knowledgeable enough to provide informed consent pertaining to the questions asked in the questionnaire regarding customer satisfaction.

Table 3.3: Table Showing the Gender Distribution of Respondents from the 3 Hospitals that
Participated in the Study

Genders	Frequency	Percent	Valid Percent	Cumulative
				Percent
Male	77	61.6	62.0	62.0
Female	48	38.4	38.0	38.0
Total	125	100	100	

Source: Field Analysis, (2021).

The descriptive analysis in Table 3.3 indicated the gender distribution of respondents in this study. The analysis demonstrated that gender of respondents was representative the differences in the number of male and female respondents. Result showed that female respondents were the majority with 77 (61.6%) and male respondents were the least with 48 (38.4%), indicating that majority of the respondents were female. This implies that there are more females than males in the study.

Table 3.4: Showing Educational Qualification Obtained by Each of the Respondents from	n
the 3 Hospitals	

Educational	Frequency	Percent	Valid Percent	Cumulative
Qualification				Percent
SSCE	31	24.8	19.0	19.0
B.Sc.	66	58.2	58.0	58.0
M.Sc.	23	18.4	24.0	24.0
PhD.	05	04.0	04.0	04.0
Total	125	100	100	100

Source: Field Analysis, (2020).

From the Table 3.4 majority of respondents had reportedly obtained bachelor's degree, 66 (58.2%), followed by respondents who had obtained Senior Secondary School Certification 31(24.8%), this is followed by respondents with a Master's degree 23 (18.4%), however, only 3 respondents indicated that the highest qualification was Doctorate Degree making up 5(4%) of the total population. Thus, it can be inferred that the majority of the respondents of the study had university education, this indicates that the respondents who were educated were more likely to report perceptions of universal health coverage is required to form opinion and responses on the items of the questionnaires.

Religious Beliefs	Frequency	Percent	Valid Percent	Cumulative Percent
Christian	75	60.0	60.0	60.0
Muslim	41	32.8	33.0	24.0
Others	09	7.2	7.0	7.0
Total	125	100	100	100

Table 3.5: Showing Religious Belief as Indicated by Each of the Respondents from the 3Hospitals

Source: Field Analysis, (2021).

From the Table 3.5 majority of respondents indicated that they were Christians, 75 (58.2%), followed by respondents who reported that they were Muslims 41(18.4%), and the least category of respondents with other beliefs 9(18.4%). Thus, it can be inferred that the majority of the respondents of the study had been Christians.

Data Presentation, Analysis and Discussion

This section presents the results obtained from the study analysis in tabular formats where inferences were drawn. The study considered the analysis of data generated from the research study in relation to the responses obtained from the questionnaire administration. A total of one hundred and twenty-five (125) were retrieved. Respondents (Nurses) at the Federal Medical Centre, Airport Road, Jabi FCT, Abuja were sixty-nine, 69 making a total of 55%, of the entire population of the study. Nurses from the Save-A-Life Mission Hospital Stadium Road, Port-Harcourt, Rivers State Nigeria were forty-one 41 making a total of 33% respondents and the nurses who participated in this study, from New General Central Hospital GRA, Asaba, Delta State, Nigeria were fifteen 15 making a total of just 12%. The responses or data retrieved from the questionnaire administration formed the basis of the following results. The responses or data retrieved from the questionnaire administration formed the basis of the following results.

Testing of Results

Nurses' knowledge of Universal Health Coverage (UHC) for inclusive and sustainable development would not significantly influence the perception of development of healthcare services in Nigeria. Below is the regression analysis for the test of hypotheses.

Table 4.1: Regression Analysis on Nurses' Knowledge of Universal Health Coverage (UHC) on Perception of Development of Healthcare Services in Nigeria

Model	Unstandardized Coefficient		standardized Standardiz efficient ed Coefficient s		Sign.	Collinearity Statistics.	
	В	Std. Error	βeta			Tolerance	df
Constant	3.651	2.674	.233	2.87	.000		
Nurses' Knowledge	3.771	.092	.384	3.67	.000	.078	1 (400)

Model Statistics

R	.455
R ²	.717
Adjusted R ²	.219
Standard Error Estimate	3.331
F Statistic	23.291
Level of Significance	.000
DW statistics	1.390

*NOTE: Field Analysis, (2021).

The regression analysis above showed that the nurses' knowledge on UHC was statistically significant on perception of development of healthcare services in Nigeria. The overall effect of nurses' knowledge on UHC on perception of development of healthcare services was significant (β = .38; F= 23.29; *p* < .00). Therefore, the null hypothesis 1 was rejected. This result implies that nurses' knowledge on UHC is a significant contributor to the perception of development of healthcare services, such that, when increased level of nurses' knowledge on universal health coverage, this increases the tendency for nurses to perceive development of healthcare services. The result further revealed R² of .71, implying that the contribution of facets of customer service contributed 71% to the overall variance on customer satisfaction. This suggests that other variables not considered in this study may account for more than 29% of the total variance observed in the study.

The contribution of the role of nurses in Nigeria would not lead to significant improvement in the perception of the universal health coverage for health workers.

Model	Unstanda Coefficie	ardized nt	Standardiz ed Coefficient		Standardiz ed		Т	Sign	Collinearity Statistics.	
	B	Std Error					Tolerance	Df		
	В		S				TOIETATICE			
			βeta							
Constant	2.93	2.342	.277		2.13	.000				
Contribution	3 80	6 4 4 1	308		3 11	000	091	1(400)		
of the Role of	0.00	0.771	.000		0.11	.000	.001	1(400)		
Nurses to										
Perception of										
UHC										
Model Statistic	cs									
R				.356	6					
R ²				.632	2					
Adjusted R ²				.341	1					
Standard Error Estimate			1663							
F Statistic			31.08							
Level of Significance			.000)						
DW statistics				3.11	11					

Table 4.2: Regression Analysis Showing the Contribution of the Role of Nurses in Nigeriato Perception of the Universal Health Coverage for Health Workers

Source: Field Analysis, (2021).

From the results above, the regression analysis above showed that there is a contribution of the role of nurses in Nigeria was significant to the improvement in the perception of the universal health services for health workers [β = .39; F = 32.77; *p* < .00]. The overall contribution of the role of nurses in Nigeria was significant to the improvement in the perception of the universal health coverage. Therefore, the null hypothesis two was rejected. This result implies that technological innovation is a significant contributor to customer satisfaction, such that, technological innovation increases, the higher the perception of customer satisfaction.

The challenges faced by nurses in Nigeria will not lead to a decline in achievement recorded in the universal health coverage. The result is presented in Table 4.3.

Table 4.2.: Regression Analysis Showing the Relationship Between Challenges Faced byNurses Would Decline in Achievement Recorded in the Universal Health Coverage

Model	Unstandardized	Standardiz	Т	Sign	Collinearity Statistics.			
	Coefficient	ed						
	В	Std. Error	Coeffici	ent			Tolerance	Df
-------------------------	-------	------------	----------	-------	------	------	-----------	----------
			S					
			βeta					
Constant	1.771	2.332	.389		3.33	.000		
Quality of	4.16	.311	.422		3.92	.000	.092	1, (400)
Service Delivery								
Model Statistics								
R				.344				
R ²				.502	2			
Adjusted R ²				.513				
Standard Error Estimate				2.44				
F Statistic				27.19				
Level of Significance				.000				
DW statistics				1.299				

Source: Field Analysis, (2021).

The regression analysis above showed that the challenges faced by nurses was statistically significant to the decline in achievement recorded in the universal health coverage [β =.42; F = 27.19; *p* < .00], therefore, null hypothesis 3 was rejected. The overall challenges faced by nurses to the decline in achievement recorded in the universal health coverage was significant. This result implied that the overall challenges faced by nurses in assessing universal health coverage is significant contributor to perception of the decline of universal health coverage, such that decrease in the overall challenges faced by nurses leads to high perception of the decline in achievement recorded in the universal health coverage. The result signifies that the nurses' knowledge of universal health coverage, the contribution of the role of nurses, as well as, when pulled together yield a multiple R of .34 and R² of .50 [F = (2, 125) = 27.19, *p* < 0.01].

Summary

This study revealed that nurses showed low political involvement and powerlessness in the process of policy making, which was consistent with the findings from previous studies (Boswell, Cannon & Miller, 2019). Focusing on the difference between Auxiliary Nurses (AN's) and Pediatric Nurses (PN's), majority of the former believed that it was important for nurses to develop evidence-based policy for managing the nursing workforce, and to ensure the continuity of the health care system, pressure groups should be lobbied, while of the latter agreed that it was the nurse's role and they should help support educational institutions in developing/implementing training programmes to meet the changing quantitative demand of healthcare delivery.

This may reflect the importance of training and education in fostering nurses' political sense, particularly their understanding of the policy making process. From the core competencies

stipulated by The Nursing Council of Nigeria, AN's are only required to practice in accordance with policies while PNs and Critical-Care Nurses (CCNs) are expected to understand the process of developing health care policies. However, attention was suggested for teaching health care policies in the curriculum for nursing education. The inadequacy of policy studies in nursing education can be reflected in the answers of the respondents to the questions about the perceived contribution to evidence-based policy making. Only ANs and PNs, respectively, claimed that they had more contribution in the development of evidence-based policy. This finding suggests that the majority of nurses feel powerless and remote from policy-making related to healthcare services.

As a result, they are indifferent to the political process leading to UHC for healthcare workers to access healthcare services in Nigeria. This phenomenon warrants the immediate attention of the nursing profession. It may be timely and appropriate to reconsider the long standing suggestion to incorporate political education in the education of nurses.

From the findings of this study, nurses with higher academic qualifications, such as the master's degree and higher, perceived a significantly higher level of importance in helping to develop/strengthen policies to improve the quality of nursing education. In recent years, the Government has proposed several major changes in elderly care policy in response to the challenges evolving from our rapidly aging society, such as strengthening primary care, emphasizing aging in place, and a voluntary health insurance scheme. Understandably, these changes mean increasing demand for both ANs and PNs at the community level.

The question is, will nurses be able to meet the demand, or an even better question may be, have nurses been prepared for it? Unfortunately, with the present ANs, PNs and CCNs mix, the answer is negative. The findings of this study reaffirmed this. It is crucial, therefore, to involve nurses in policy-making, particularly when a major change is expected to occur. To ensure nurses are competent in the political process, the professional body such as The Nursing Council of Nigeria should consider revising nursing curriculum to increase nurses' knowledge on the universal health coverage.

Conclusion

Universal health care evolves from the 'Health for All' movement advocated by the WHO in the 1970s. Since then, the Nigerian government has launched many initiatives in order to achieve UHC, particularly for inclusive and sustainable healthcare services for healthcare workers such as nurses. Although the outcomes of these initiatives are yet to be seen, the researcher and her supervisor considered it to be appropriate to conduct the reported survey to identify nurses' knowledge of and involvement in the process, including policy-making and implementation. It was hoped that the findings would inform major stakeholders of some issues which may possibly affect the success of these initiatives.

The survey has revealed some knowledge gaps among nurses. Their knowledge of healthcare financing, including health insurance, drug-dispensing, and human resource policy needs to be

enhanced. The low perceived importance and contribution to the sustainable development of elderly healthcare services are deterrents to their possible involvement in the initiatives. After all, nurses constitute a major work force in healthcare. They should be better prepared to participate with policy-making knowledge for the benefit of the population that they serve.

Recommendations

Since the demand for healthcare services will increase in the future. To meet the escalating demand, the government needs to allocate additional resources, be they human or financial, to prepare the society. The nurses constitute the major healthcare workforce in Nigeria. There is no reason for nurses to have such low level knowledge of the universal health coverage and to be unprepared for this forthcoming challenge. Based on the findings, the following recommendations were made for this study.

- It is crucial, therefore, to involve nurses in policy-making, particularly when a major change is expected to occur. To ensure nurses are competent in the political process, the professional body such as Nursing Council of Nigeria should consider revising the indicated nursing curriculum and core-competency of nurses to strengthen the nurses' knowledge and ability to participate in policy development. Thus, the gap between policy and practice could be bridged.
- Since nurse educators are responsible for nurturing the future generation of nurses, they should be role models for their students, and should equip themselves well in this area. There is an urgent need to involve more nurse educators in the political process leading to decision-making.
- 3. The survey uncovered a considerable knowledge gap in nurses' knowledge of UHC, but care must be taken in interpreting the findings from such a non-random sample. Having collected the data on nurses' perceived contribution and importance to policy-making across clinical, management and education sectors, the research team believes that, with the increase of the aged population, regulatory bodies such as the Nursing Council of Nigeria could do more to enhance their capacity at various fronts to support the government's initiatives to provide UHC for nurses and other healthcare workers.
- 4. To ensure that more knowledge with regards to universal health coverage for nurses in Nigeria, the National Health Insurance Scheme (NHIS), National Primary Healthcare Development Agency (NPHCDA) as well as, the Hospital/Healthcare Management Boards (HMO's) under the auspices of Ministry of Health are encouraged to reform the healthcare policy mandate nurses and other allied healthcare workers are to attend and actively participate in seminars, conferences and workshops on universal health coverage so as to assuage and increase knowledge regarding universal health coverage as it concerns health workers especially nurses in Nigeria.

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Tsunami Preparedness in Indonesia: The WAVES Initiative

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Abstract

The Indonesia archipelago is highly vulnerable to earthquakes and tsunamis. The WAVES initiative uses experts in geology, engineering, communications, public health, and geology in a multi-disciplinary, cross-cultural effort to better understand and communicate risk to federal and local government agencies, schools, businesses, and communities. Efforts include logging trenches dug on coastal plains to prospect for historical tsunami deposits, developing localized inundation maps, conducting social surveys on perceptions of tsunami threat and efficacy, creating and delivering educational sessions including the "20/20/20 principle" to schools and communities, identifying localized safe zones out of the inundation zone and within a timely walking distance, conducting tsunami evacuation drills, mapping evacuation signs, conducting interviews, and working with local and federal government officials and schools to create evacuation plans. This paper details our research findings and corresponding educational intervention.

Keywords: Tsunami, Indonesia, Natural Hazards, Education, Mitigation

Introduction

Natural Hazards in Indonesia

Geophysical hazards in the Indonesian archipelago arise from its unique geological setting at the collisional junction of three of Earth's largest tectonic plates. Most of Indonesia is on the southeast edge of the Eurasian Plate, which is surrounded by convergent plate boundaries. The Indo-Australian Plate converges from the south and the Pacific Plate from the east. The rapid convergent motion of these plates is buffered by the episodic release of pent-up energy in the form of volcanic eruptions, earthquakes, and associated tsunamis and landslides (Harris and Major, 2017). Indonesia is the fourth most populous country in the world at over 272 million people (Badan Pusat Statistik, 2022). The Indonesian population has more than quadrupled since the 1950s and is rapidly increasing (Our World in Data, 2022). Even relatively minor natural hazards over the last few decades have resulted in greater numbers of fatalities than those of the past.

Tsunamis in Indonesia have occurred once every four years on average over the past 430 years (Latief, Puspito, and Imamura, 2000). The temporal distribution of the seismic events over the past 100 years indicates a 20-30 year alternating cycle of frequent seismic activity followed by seismic quiescence (Harris and Major, 2017). The last period of quiescence began during the

mid-1980s and came to an end in 2004 when the Great Sumatra earthquake triggered the deadliest natural disaster in the 21st century. The 9.2 magnitude earthquake was the third largest ever recorded and was caused by the rupture of a gigantic segment of the boundary between the Asian and Australian plates off the northwest coast of Sumatra and Andaman Islands. The earthquake itself caused several buildings to collapse and killed hundreds of people. The plate rupture occurred at an ocean depth of more than 3,000 meters. A massive amount of water was displaced, producing the largest earthquake-generated tsunami in recorded history. The tsunami killed more than 283,000 people; the majority were in Indonesia (Lay et al., 2005). There had not been any earthquakes larger than magnitude 8.5 globally for 39 years prior to this event (USGS, 2022).

Three months after the Great Sumatra Earthquake, the plate boundary segment immediately to the south ruptured, producing a magnitude 8.7 earthquake and large tsunami that claimed thousands of lives. This event was followed in 2006 by a magnitude 6.3 earthquake near Yogyakarta that killed around 6,000 persons and displaced nearly half a million more. This event was nearly identical to what is found in historical records and was forecast to reoccur in central Java (Harris and Prasetyadi, 2002). Two months after the seismic disaster in Yogyakarta, a magnitude 7.7 earthquake struck south of the city, but offshore, which generated a tsunami that killed hundreds of people. In 2007, a magnitude 7.5 earthquake struck near Jakarta, a megacity with a population of about 13,000 people per square kilometer (Martinez and Masron, 2020). Two months later, a series of earthquakes (magnitudes 8.5, 7.9 and 7.1) struck the southwest coast of Sumatra causing more fatalities. In 2008, three aftershocks between magnitude 7.0-7.5 caused fatalities. In 2009, there were four destructive earthquakes between magnitude 7.0-7.9 that accounted for more than 2,500 fatalities in Sumatra. In 2010, three more earthquakes between magnitude 7.2-7.9 caused hundreds of fatalities, including the 2010 Mentawai tsunami. A few hours before the 7.9 event, Merapi, a volcano in central Java, exploded with an intensity unseen since 1870. At least 200 fatalities resulted. Fortunately, close to 350,000 people were evacuated immediately before the eruption. In 2012, a magnitude 8.6 earthquake struck off the coast of northern Sumatra and was followed two hours later by a magnitude 8.2 earthquake near the same location. Additional fatalities from earthquakes occurred each year from 2013-2017.

A host of disasters occurred in various parts of Indonesia in 2018, all striking in densely populated areas. Five strong earthquakes struck Lombok killing over 500 people and displacing over 4 million inhabitants. In September, a magnitude 7.5 earthquake struck the Palu area of western Sulawesi. The earthquake generated hundreds of landslides, several of which occurred under the sea and caused destructive tsunamis. Massive mudflows associated with liquefaction demolished large areas of the city. Over 5,000 people died. In December, the partial collapse of Krakatoa volcano into the Sunda Strait generated a 'silent' tsunami that crashed into coastal communities, killing over 400 people. A paper in 2012 warned of the likelihood of this event (Terry and Goff, 2012). From 2019 to 2021, an additional 17 earthquakes have caused fatalities in Indonesia including four events >7.0 magnitude and one event in Sulawesi that caused over 100 fatalities in 2021 (USGS, 2022).

Tsunami disaster mitigation research in Indonesia began in earnest in North Sumatra and elsewhere *after* the 2004 Great Sumatra Earthquake. Since then, tsunamis have occurred in Indonesia in Nias in 2005, Java in 2006, Mentawai in 2010, and Sulawesi in 2018. Indonesia has around 54,720 kilometers of coastline, much of which is vulnerable to earthquake-triggered tsunamis (Embassy of Indonesia, 2022). More destruction is likely to occur before the seismic mega-cluster ends. Increased earthquake and tsunami mitigation measures are needed to reverse the growing loss of life and property.

Current Tsunami Mitigation Efforts

Since the 2004 Indian Ocean tsunami, efforts to describe and analyze what can be learned from past tsunamis and how to prepare for the future have increased around the world (Jain, Virmani, and Abraham, 2021; Repetto, Cordón, and Bronfman, 2022; Dhellemmes et al., 2021; Chen, Lindell, and Wang 2021; Rasyif et al., 2020; Sun, 2020; Wegscheider et al., 2011). Current tsunami mitigation efforts include Early Warning Systems, structural measures, construction of Temporary Evacuation Shelters (TES), and community education including identifying tsunami evacuation zones, evacuation planning, and tsunami evacuation drills.

Despite progress in Early Warning Systems (EWS) (Safri et al., 2020; Harig et al., 2020) several studies have found the systems insufficient to warn individuals in the event of a tsunami. A recent study in Indonesia found a lack of operational communication networks to relay warnings to those who are vulnerable (known as 'the last mile' problem) (Rahayu et al. 2020). Another study in Aceh Indonesia found a lack of community engagement in EWS (Sufri et al. 2020). Since the implementation of Indonesia's EWS in 2006 there have been six tsunamis, yet those at risk were often not warned in time to evacuate. Either the warning was not received until after the tsunami struck, the warning was terminated early and people returned to low ground only to be hit with a second wave, or the warning underestimated the tsunami hazard (Suppasri, 2015). A combination of challenges is responsible for the failure of these technology-based early warning systems including the short distance between where the tsunami forms and the coastlines they impact. Most tsunamis are generated by earthquakes along the subduction interface of convergent plate boundaries surrounding Indonesia. For example, the Sumatra and Java Trenches are only 200-300 km offshore. In deep water, tsunamis travel at speeds of 600 km/hr, which means that there is only 20-30 minutes from the time the tsunami forms until it arrives. Additionally, EWS are not always properly maintained. This suggests recognition of natural warning signs and immediate self-evacuation is timelier and more beneficial than waiting on a siren prior to evacuating (Hall et al. 2017).

Natural tsunami barriers such as coral reefs and mangrove forests have been depleted due to tourism, shrimp farms, and foreign wood export (Niman, 2010; Barbier, 2006). Structural disaster mitigation measures include building vegetative barriers to absorb some of the energy of the tsunami waves (Danielsen, 2005; Muhari et al., 2012). The identification of tall sturdy buildings for evacuation or construction of Temporary Evacuation Shelters (TES) in low-lying areas is needed (Kemal 2020; Nakaseko et al., 2008; Hein, 2014). TES resemble parking garages with wide staircases for climbing and an open roof designed to hold a large number of people above

the water. Establishing trust in these structures has been problematic, particularly in Aceh where lack of local input is perceived as government control (Spahn et al. 2010). Another important structural measure is placement of tsunami evacuation signs. These signs are now common occurrences in coastal communities in Indonesia prone to tsunamis. Although signage directs individuals where to go in the event of a tsunami, they do not state under what circumstances to evacuate (e.g., after observation of a natural warning sign such as an earthquake or receding ocean), nor do they communicate the urgency of evacuation immediately after an earthquake (Hall et al. 2017).

Geohazard education and implementation of disaster mitigation strategies are needed to reverse the growing losses to natural disasters. Health communication research suggests creating high-threat (susceptibility and severity) and high-efficacy (self-efficacy and response efficacy) messages will be most effective in encouraging behavior change (Witte and Allen 2000). Messages related to tsunami threat may include communicating information about risk through tsunami modeling and identification of inundation zones. Efficacy components may focus on educating those at risk to recognize natural tsunami warning signs and to immediately self-evacuate to high ground rather than waiting for a siren which can cause deadly delays. Another efficacy component includes identifying safe locations that can be reached by foot in a timely manner. Furthermore, tsunami evacuation drills increase efficacy by allowing communities or individuals in at-risk areas to practice evacuation behavior before a disaster occurs (Hein, 2014; Nakaya et al., 2018; Sun and Yamori, 2018). In 2017, the United Nations Development Programme set out to increase tsunami awareness for school children in 18 countries of Asia and the Pacific. From 2017-2018 over 61,000 students, teachers, and administrators in 115 schools participated in evacuation drills (United Nations Development Programme, 2019).

WAVES Initiative

The WAVES research consortium involves multi-disciplinary researchers and students from government agencies and universities in Indonesia and the United States. The mission of WAVES is to assess and communicate risk of natural hazards and implement risk reduction strategies. The Indonesian government has adopted the 20-20-20 principle for tsunami risk reduction, which was developed by WAVES. Generally, if ground shaking from an earthquake lasts more than 20 seconds, nearby coastal communities have around 20 minutes to evacuate to 20 meters elevation for safety (Hall et al. 2017). Although there are many exceptions to the rule, such as tsunamis caused by landslides or volcanic eruptions, the 20-20-20 rule empowers those in harm's way to self-evacuate in a majority of the regions in Indonesia threatened by tsunami hazards. WAVES collaborates with local government leaders and natural disaster mitigators. Community-based activities include natural hazards education, including earthquake and tsunami evacuation drills. WAVES includes PhD's and government leaders in geology, engineering, communication, public health, and geography. The geology and engineering team focuses on assessing natural hazard risk, such as earthquakes and tsunamis. Estimates of seismic ground motion and tsunami inundation from historical and geological records provide a way to make numerical models of previous and likely major earthquake and tsunami events. The public health team focuses on community assessments to determine perceptions of tsunami risk and behavioral intentions. The

team uses this information to develop key messages and tsunami preparedness campaigns. The geography team identifies safe evacuation areas out of the inundation zone, conducts tsunami evacuation drills, and discusses evacuation plans with government officials. All fields work together to better understand local perceptions related to tsunamis and provide educational sessions to communities and schools in at-risk coastal areas.

Methodology

Geological and Geophysical Research Methods

Using the principle that the past is the key to the present we query historical and geological records of past earthquake and tsunami events to identify areas most at risk. These methods involve logging trenches dug on coastal plains to prospect for tsunami deposits. We have discovered that many coastal cities are partially built on these deposits from previous tsunamis. Age analysis of the deposits provides a chronology of tsunamis that reaches back thousands of years. We also analyze historical accounts of earthquake and tsunami events that provide more detail about the impact of these events when they happen again (Harris and Major, 2016).

With these data we construct numerical models that reconstruct many pre-instrumental earthquake events to determine the likely source, magnitude and recurrence intervals. The time difference between when the earthquake occurs and when the tsunami arrives at several different locations provides a method of tracing where the tsunami was generated. The height of the waves provides a way to estimate the earthquake magnitude. We are able to reconstruct these events using Bayesian statistical models and machine learning that aid in developing tsunami inundation maps that inform coastal zoning plans and evacuation drills.

The methods we use to assess risk of earthquakes and tsunamis are varied. For example, we employ a method known as Vs30 to determine the way the upper 30 meters of Earth's surface will respond during an earthquake. The method involves striking a metal plate with a sledge to produce shock waves recorded by multiple sensors to determine how fast these waves move through the ground. If the shock waves move slowly the site is prone to amplification of seismic waves and much more damage than other areas, even if these sites are far away from the epicenter. From our measurements we have mapped out many densely populated areas with low Vs30 values. These maps are essential for urban planning and earthquake zoning. We have also used ground penetrating radar and high-resolution drone surveys to map out the extent of tsunami deposits we discovered. As a result, we have discovered several areas previously inundated by tsunamis where the extent of inundation is estimated and used in inundation maps (Harris et al., in press).

Social Survey

We conducted social surveys to inform the development of our educational interventions. The pencil/paper survey was delivered in Indonesian and contained several categories of questions: (1) demographic (e.g., sex, island of residence), (2) earthquake and tsunami risk and efficacy

perceptions on a 1-5 Likert scale from strongly disagree to strongly agree. (3) personal warning preferences, and (4) behavioral intentions. The survey was validated in previous research (Hall et al. 2017). The surveys were conducted in coastal schools (N=50) in Java, Bali, Lombok, and Sumba. Schools were identified by leaders in Indonesia's regional governmental disaster management agency 'Badan Penanggulangan Bencana Daerah' (BPBD). Adolescents aged 12-18 (N=2,386) individually filled out surveys in class. We used Pearson's Chi-square to compare the sampling distribution of sex across islands and no significant differences were found at p < 0.5. Descriptive statistics were used to analyze the number and percentage for each response by island and in total. We calculated the means and standard deviations for earthquake and tsunami susceptibility and efficacy perceptions for each island. Welch's ANOVA was used to determine differences in perceptions of threat and efficacy across the four islands. Significant findings were probed with the post hoc Games-Howell test. We used independent t-tests to determine whether there were significant differences in threat and efficacy perceptions by sex. We also used a stepwise logistic regression to determine the associations of additional demographic variables, tsunami information sources, and prior hazard experience with tsunami threat and efficacy perceptions; however, these are reported in another paper and will not be discussed here (Hall et al., in Press).

Educational Intervention

The researchers, BPBD officials, and students from Indonesia and the United States developed and delivered an approximately one-hour long educational presentation that included lecture, images, videos, maps, stories, songs, games, and movement. The educational intervention included key messages based on previous survey results. The main intent of the presentation was to stress the tsunami vulnerability of coastal Indonesia based on historical evidence, to encourage the use of the 20-20-20 guidelines, to stress the importance of immediate selfevacuation instead of waiting for a siren or government warning, and to identify an evacuation plan. Most of our presentations were given in schools, but we also presented to communities, factories, and officials in government, disaster preparedness, and tourism. We conducted evacuation drills for each school that desired. This consisted of a 20-second earthquake drop/cover/hold followed by practicing a walking route to a safe high ground out of the inundation zone identified in our previous tsunami mapping. In every drill we were able to evacuate all students to safety in less than 20 minutes. Before and after our educational intervention, we conducted informal interviews about tsunami perceptions and evacuation intentions with government officials, teachers and school administrators, community members, and students. While these interviews were not intended to serve as formal research findings, they provide additional directions for future research on religious, economic, and political factors related to tsunami mitigation. We also followed existing evacuation signs and discussed current community evacuation plans with community leaders.

Results

Geology Results

The most significant results of our geological and geophysical research have been the discovery of geological and historical records of earthquakes and tsunamis and using these data in developing risk assessments for densely populated regions of Indonesia. We compiled and translated historical accounts of earthquake and tsunami events of Indonesia (Harris and Major, 2016) to reconstruct several natural disasters in the past that claimed many lives. Reconstructing the 1852 Banda Sea earthquake provided a way to test a new code we developed that uses Bayesian statistical methods to predict the location, geometry and size of the earthquake from anecdotal accounts (Ringer et al., 2021). These results provide a way to incorporate historical accounts into seismic risk assessments and therefore extend the record of earthquakes and tsunamis much further back in time than instrumental records of earthquakes (<80 years). Since most fault zones have earthquake recurrence intervals of hundreds to thousands of years, we now have a way to estimate where and how large these events were and then how much strain energy has since accumulated on various fault zones.

One of the most important geological discoveries is the common occurrence of boulder ridges on the south coast of Java and other islands adjacent to the eastern Sunda subduction zone. This subduction zone is interpreted as incapable of producing mega-thrust earthquakes and large tsunamis due to the lack of instrumental records and historical accounts of earthquakes > 7.9 (Newcomb and McCann, 1987). However, we discovered sparsely preserved layers of sand from tsunamis with ages of 500 and 1000 years before present and well preserved imbricated boulder ridges that were most likely formed by tsunamis (Harris et al., in press). The ages and extent of these tsunami deposits indicate that the eastern Sunda subduction zone is capable of producing megathrust earthquakes and giant tsunamis. This discovery changes the earthquake and tsunami risk assessment for the densely populated coastal cities in this region.

Social Survey Results

Participants (N=2,386) resided in Java (N=649), Bali (N=388), Lombok (N=432), and Sumba (N=917). Our independent t-tests for sex indicated significant differences in perceptions of earthquake susceptibility, tsunami susceptibility, and tsunami efficacy. Females (M=3.53, SD=1.13) had a significantly higher mean for perceptions of earthquake susceptibility compared to males (M=3.37, SD=1.27); t(1881.99)=-3.07, SE=.05, p=.00. Females (M=3.30, SD =1.21) also had a significantly higher mean for perceptions of tsunami susceptibility compared to males (M= 3.11, SD = 1.35); t(1875.54)=-3.44, SE=.06, p=.00. However, males had a significantly higher mean perception of tsunami efficacy (M=3.37, SD =1.22) compared to females (M= 3.22, SD = 1.15), t(1936.06) = 3.00, SE=.05, p=.00. Java had a significantly higher mean perceived susceptibility for both earthquakes (M=3.81) and tsunamis (M=3.91) compared to other islands. Mean perceptions of both earthquakes (M=3.05) and tsunamis (M=2.69) were significantly lower in Sumba.

Table 1 shows mean perceptions of earthquake susceptibility, tsunami susceptibility, and tsunami efficacy for the four islands. There were significant differences in perceptions of earthquake susceptibility at the p=.05 level between the islands [F(3, 1145.93) = 56.27, p=.00]. Post hoc comparisons indicated no significant difference (p=.99) in mean perceptions of earthquake susceptibility between Bali and Lombok. However, mean perception of susceptibility to earthquake was significantly higher in Java compared to Bali (p=.00, SE=.06, 95%CI=.09, .38), Lombok (p=.01, SE=.07, 95%CI=.03, .40) and Sumba (p=.00, SE=.06, 95%CI=.61,.92). Mean perceptions of earthquake susceptibility were significantly higher in Bali compared to Sumba (p=.00, SE=.06, 95%CI=.37, .69). Mean perceptions of earthquake susceptibility were significantly higher in Lombok compared to Sumba (p=.00, SE=.07, 95%CI=.37, .74). We also found significant differences in perceptions of tsunami susceptibility [F(3, 1141.29) = 127.91,p=.00]. Post hoc comparisons again showed no significant differences between Bali and Lombok (p=.96) while showing significant differences between all other islands at the p<.05 level. Mean perceptions of tsunami susceptibility were significantly higher in Java compared to Bali (p=.00, SE=.06, 95%CI=.54, .86), Lombok (p=.00, SE=.07, 95%CI=.48, .85), and Sumba (p=.00 SE=.06, 95%CI=1.1, 1.4). Mean perceptions of tsunami susceptibility were significantly higher in Bali compared to Sumba (p=.00, SE=.06, 95%CI=.36, .68) They were also significantly higher in Lombok compared to Sumba (p=.00, SE=.07, 95%CI=.37, .74). There were significant differences in perceptions of efficacy in the event of a tsunami [F(3, 1132.78) = 11.75, p=00]. Post hoc comparisons showed no significant differences between Bali and Lombok (p=.47) or Bali and Sumba (p=.58). Mean perceptions of efficacy were significantly higher in Java compared to Bali (p=.00, SE=.06, 95%CI=.11, .44), Lombok (p=.00, SE=.07, 95%CI=.20, .56), and Sumba (p=.01, SE=.06, 95%CI=.03, .35). They were also significantly higher in Sumba compared to Lombok (p=.04, SE=.07, 95%CI=.01, .37).

<u>Variable</u>	<u>Java</u> M (SD)	<u>Bali</u> M (SD)	<u>Lombok</u> M (SD)	<u>Sumba</u> M (SD)	<u>Sig</u> .
Sus. Quake	3.81 (.98)	3.58 (.82)	3.60 (1.17)	3.05 (1.37)	.00*
Sus. Tsunami	3.91 (1.11)	3.21 (.88)	3.25 (1.17)	2.69 (1.33)	.00*
Eff. Tsunami	3.47 (1.08)	3.20 (.94)	3.09 (1.12)	3.28 (1.35)	.00*

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^aANOVA results; asterisks indicate there was a significant difference between two or more message groups at p<.05.

Slightly fewer than half of our total survey participants either *agreed* or *strongly agreed* that they are susceptible to a tsunami. Participants who *agreed* or *strongly agreed* they were susceptible to a tsunami varied substantially depending on location: Java (77.2%), Lombok (49.3%), Bali

(37.6%), and Sumba (35.9%). 31.8% of total survey participants *disagreed* or *strongly disagreed* they are susceptible to a tsunami. More than a quarter of survey participants in Lombok and more than half in Sumba *disagreed* or *strongly disagreed* that they are susceptible to a tsunami. Fewer than half of total participants (48.5%) *agreed* or *strongly agreed* they would be able to save themselves in the event of a tsunami. Over half of participants in Java (57.2%) and Sumba (52.9%) *agreed* or *strongly agreed* they would be able to save themselves in the event of a tsunami. This was only true for about one-third of participants in Bali (36.9%) and Lombok (36.4%). Many participants *disagreed* or *strongly disagreed* that they would be able to save themselves in Java (21.3%), Bali (21.4%), Lombok (31.9%), and Sumba (33.9%).

Table 2 shows cross-tabulation results for perception of tsunami risk and efficacy perceptions, preferred warning preferences, and behavioral intentions. The overall preferred warning preference of participants was a siren followed by tv and then natural warning signs. 76.7% of participants in Java reported that they would evacuate after observing natural warning signs compared to 58.8% in Sumba. The most common overall evacuation intention circumstance was an order or alert from the authorities although the percentage was higher in Java (84.7%) compared to all other islands (62-67%). Uphill evacuation was the most common evacuation intention location followed by inland, and then climbing the stairs to a tall building. 93.4% of participants in Java reported they would evacuate uphill compared to only 65.7% in Bali. 48.7% of participants in Bali reported they would climb the stairs of a tall building, compared to 26-29% of participants on other islands.

Question (N, %)	Java (N=649)	Bali (N=388)	Lombok (N=423)	Sumba (N- 917)	Total (N=2,386)
Earthquake Susceptibility Str. Disagree Disagree Neutral Agree Str. Agree No Answer	30: 4.6% 45: 6.9% 65: 10.0% 382: 58.9% 124: 19.1% 3: 0.5%	10: 2.6% 14: 3.6% 141: 36.3% 181: 46.6% 38: 9.8% 4: 0.3%	39: 9.0% 35: 8.1% 74: 17.1% 192: 44.4% 90: 20.8% 2: 0.5%	183: 20.0% 155: 17.0% 131: 14.3% 314: 34.2% 126: 13.7% 8: 0.9%	262: 11.0% 249: 10.4% 411: 17.2% 1069: 44.8% 378: 15.8% 17: 0.7%
Tsunami Susceptibility Str. Disagree Disagree Neutral Agree Str. Agree	39: 6.0% 46: 7.1% 58: 8.9% 294: 45.3% 207: 31.9%	15: 3.9% 53: 13.7% 171: 44.1% 128: 33.0% 18: 4.6%	46: 10.6% 65: 15.0% 103: 23.8% 164: 38.0% 49: 11.3%	212: 23.1% 268: 29.2% 102: 11.1% 245: 26.7% 84: 9.2%	312: 13.7% 432: 18.1% 434: 18.2% 831: 34.8% 358: 15.0%

Table 2. Perceptions of Earthquake and Tsunami Risk and Efficacy, Warning Preferences, and Behavioral Intentions

No Answer	5: 0.8%	3: 0.8%	5: 1.2%	6: 0.7%	19: 0.7%
Tsunami Efficacy Str. Disagree Disagree Neutral Agree Str. Agree No Answer	29: 4.5% 109: 16.8% 135: 20.8% 270: 41.6% 101: 15.6% 5: 0.8%	13: 3.4% 70: 18.0% 157: 40.5% 114: 29.4% 29: 7.5% 5: 1.3%	29: 6.7% 109: 25.2% 131: 30.3% 107: 24.8% 50: 11.6% 6: 0.7%	114: 12.4% 197: 21.5% 111: 12.1% 289: 31.5% 196: 21.4% 10: 0.01%	185: 7.8% 485: 20.3% 534: 22.4% 780: 32.7% 376:15.8% 26: 1.1%
Warning Preferences Local leader Cell phone Radio Siren Nat. Warning TV Other	49: 7.6% 67: 10.3% 78: 12.0% 262: 40.4% 135: 20.8% 170: 26.2% 31: 4.8%	37: 9.5% 65: 16.8% 48: 12.4% 189: 48.7% 127: 32.7% 85: 21.9% 6: 1.5%	70: 16.2% 76: 17.6% 76: 17.6% 109: 25.2% 149: 34.5% 156: 36.1% 16: 3.7%	76: 8.3% 121: 13.2% 195: 21.3% 69: 7.5% 300: 32.7% 372: 40.6% 35: 3.8%	232: 9.7% 329: 13.8% 397: 16.6% 985: 41.3% 711: 29.8% 783: 32.8% 88: 3.7%
Evacuation Circumstances Alert from authority Family/Friend Others Evacuating Natural Signs Would not evacuate	550: 84.7% 283: 43.6% 481: 74.1% 498: 76.7% 24: 3.7%	256: 66.0% 87: 22.4% 94: 24.2% 239: 61.6% 5: 1.3%	290: 67.1% 116: 26.9% 124: 28.7% 278: 64.4% 10: 2.3%	575: 62.7% 266: 29.0% 271: 29.6% 539: 58.8% 31: 3.4%	1671: 70.0% 752: 31.5% 970: 40.7% 1554: 65.1% 70: 2.9%
Evacuation Intentions Climb building Go up hill/mountain Go toward ocean Go inland Stay in house Other	189: 29.1% 606: 93.4% 17: 2.6% 563: 86.7% 12: 1.8% 71: 10.9%	189: 48.7% 255: 65.7% 11: 2.8% 208: 53.6% 6: 1.5% 13: 3.4%	113: 26.2% 331: 76.6% 10: 2.3% 264: 61.1% 8: 1.9% 65: 15.0%	267: 29.1% 765: 83.4% 23: 2.5% 477: 52.0% 18: 2.0% 64: 7.0%	758: 31.8% 1957: 82.0% 61: 2.6% 1512: 63.3% 44: 1.8% 213: 8.9%

*Select all that apply question results in over 100% when responses are totaled.

Results of Geographical Survey

This section outlines findings outside the survey results, considering various additional aspects of preparedness island by island.

All three cities that we surveyed in Java (Pelabuhan Ratu, Pangandaran, Pacitan) had mapped evacuation routes and identified gathering places. Along these routes, posted orange signs with a large rolling wave and a person running up a hill pointed the way (see *Figure 1*). In Pelabuhan Ratu the signs also included information listing the name of the evacuation destinations (park, hospital, government building etc.) and the distance, usually less than 1.5 kilometers.



Figure 1. Evacuation signs in Pelabuhan Ratu. All photos by Chad Emmett.

Interviews with many local leaders demonstrated a fear that they would be shamed if they called for an evacuation and no tsunami occurred. This included the head of the Indonesian Hotel and Restaurant Association (PHRI) for the Sukabumi regency, Dadang Hendar, and the village chief of Cimaja who said: "If there is a twenty second earthquake and we evacuate, but there is no tsunami, then we have evacuated for nothing." There is still confusion as to who is actually in charge of educating and preparing people for tsunami mitigation and sounding the alarm. The head of PHRI was in favor of identifying and marking evacuation routes and having hotels inform each guest about evacuation procedures but noted that this was the "duty of the country and not the duty of the hotels." There was a perception that interest in tsunami awareness wanes over the years as memories of past tsunamis fade. The village chief of Cimaja mentioned that they had held a practice evacuation five years ago. He related that since there had not been a tsunami, people lost interest in continuing to hold evacuation drills. The principal of the Pacitan Middle School 3 stated that his school had never held an evacuation drill. The fact that his school in the center of the coastal plain was 3-5 kilometers from any high ground made holding an evacuation drill most challenging due to time and distance. The principal stated that he assumed that tsunamis would happen at night when the children were in their own homes. He also believed that the police would drive through town with a siren telling people to evacuate.

The town of Pacitan with its surrounding villages was perhaps the best prepared. It was often women volunteers who were most involved and effective in the day-to-day tsunami mitigation efforts. They commented that their involvement was due in part their motherly instincts of wanting to help and save others. The village of Kembang in southeastern Pacitan was one of the first municipalities that the BPBD worked with in 2013 to help with tsunami preparedness. Large signs in the village show inundation areas, evacuation routes, and safe gathering places (see *Figure*

2). Additionally, the village widened and paved a path through rice paddies for easier evacuation and built two evacuation stairways up steep wooded hillsides to safe higher ground.



Figure 2. Directional sign along the evacuation route.

We were invited to host six evacuation drills in Pelabuhan Ratu. Reasons for not holding practice drills cited by school administrators included time constraints, unsafe evacuation routes due to heavy traffic, midday heat, and drills recently held or drills already scheduled for a future date. The drills that were held provided an excellent learning experience and in some cases drew attention to problems. We held our first evacuation drill in the village of Cidadap. It was a hot, humid and sunny midday. This proved to be our first introduction to the fact that adults are less inclined to participate in the heat. Cidadap had no evacuation signs or marked evacuation routes. The village leaders offered to drive us to the designated gathering point, but it was a circuitous route and defeated the purpose of empowering people to save themselves, preferably without relying on cars that can get stuck in traffic and in this case took them closer to the more vulnerable coast before heading inland to the hills. When asked, the children knew which way to go. To practice we used our phones to set a timer and identity our elevation and then set out with 50 children and one father walking through the village, across the rice fields--walking on foot wide banks between the flooded fields, through another cluster of houses and then climbing up a tree covered hillside to a safe elevation (see *Figure 3*). It took 15 minutes to get to safety.



Figure 3. Evacuation drill in Cidadap.

In Cisolok, the Junior High School is located across the coastal road from the beach and is very vulnerable. The village had never held a practice drill, but the school had held its first tsunami simulation practice two years earlier. For that event, students ran up the hill, 300 meters in 3 minutes, to pre-designated areas for each class. Administrators were happy to do it again. After a morning of presentations, more than 600 eighth and ninth graders left the school yard via a back gate and walked 300 meters up the hill to a safe elevation of 40 meters (see *Figure 4*). Then the first in line all sat down on the side of one lane road while waiting for the rest to arrive. Within 10 minutes all of the students were at a safe elevation. Afterwards, the physical education teacher observed that "it would be good to have evacuation practices every year at school."



Figure 4. Evacuation drill in Cisolok.

The easiest and most convenient evacuation drill we held was in the center of Pangandaran. All the elementary school children had to do was walk 50 meters to the end of the street, climb over a median planter in the center of the city's main street and then go to the second floor (the women's prayer section) of the main mosque which is a designated tsunami gathering place. Since the 2006 tsunami, Pangandaran has held annual evacuation drills so the children at this

school knew exactly where to go. While the second floor was high enough to provide protection during the 2006 tsunami, it would not have survived an Aceh strength tsunami. An encouraging development in Pangandaran is the recent opening of a Temporary Evacuation Shelter (TES) closer to the coast.

During the 2006 tsunami the small village of Masawah (located right on the coast and about 30 kilometers west of Pangandaran) lost 47 residents to the wave. Most were at work or at home and had not evacuated because they had not been taught that even a low intensity earthquake could be a sign of a tsunami. There was no warning from the government or local leaders either. To ensure that more people survive the next tsunami, the village erected a memorial made of an actual fishing boat that was broken in two by the tsunami as a reminder of what could happen again and as an incentive to be prepared for the next natural disaster. In the village elementary school about 40 students participated in our evacuation drill. They first sought shelter under their desks while the earth "shook" then they ran through the village and up a steep hill via a cement stairway (installed after the last tsunami) to safety (see *Figure 5*). It took only a matter of minutes. The children knew exactly where to go and the cement stairway made it easy for everyone to easily ascend what could be a muddy, slippery mess during the rainy season.



Figure 5. Evacuation drill in Masawah.

The village of Sidomulyo to the east of Pacitan had recently been awarded the provincial (East Java) prize for "self-reliance" because of its grassroots efforts to be prepared and trained for disasters. Practice evacuations were regularly held. At the start of our evacuation drill, children took off out the front gate on a predetermined and marked evacuation route. After about 200 meters inland the students knew to cross over a drainage ditch (a bottleneck in the evacuation route) on a log. Here the local leaders had the students stop, saying they had gone far enough. Of concern to our team was the fact that an elevation of 20 meters had not yet been reached. Further inspection of the rest of the route revealed that beyond the grove of trees the route ended at the base of a long and tall rock cliff. This thirty meter high rock face could be surmounted by

agile adults and older youth, but it would be nearly impossible for the elementary school children to scale to a safe elevation. Later, back at the school when asked about this problem, local officials readily noted that they were very aware of this problem and that previous evacuation plans had called for building some sort of steps up the side of the cliff, but they were held back by inadequate funding. Also planned, but pending funding is adding a gate to the inland side of the school yard so that evacuees don't have to exit via the seaward front gate of the school yard.

Bali not only had tsunami warning signs, marked evacuation routes, and designated gathering points, but also had monthly evacuation drills, a workable EWS, published brochures with tsunami evacuation information and maps of inundation zones, and a certification program that identified Tsunami-Ready hotels. Ida Bagus Purna Sideman, the executive director of the Indonesian Hotel and Restaurant Association, noted that it was only after the 2004 Indian Ocean tsunami that Bali began to be aware of tsunami danger. Since then, there have been ongoing efforts to properly ensure that local Balinese and visiting tourists are more aware of and better prepared for tsunamis. Tsunami mitigation efforts in Bali's thriving hotel industry got their start in October of 2013 when the Asia-Pacific Economic Cooperation (APEC) forum held its 25th annual gathering in Bali. In preparation for the meeting, embassies of the participating countries requested that local police conduct security inspections of event hotels. The initial security concerns focused primarily on terrorism; however, while making their inspections, the police happened upon a Tsunami Ready Certificate in a major hotel in Nusa Dua-an Indonesia based company that advises, trains, and certifies hotels and other tourism related businesses on tsunami preparedness. The certificate was passed on to the local Tourism Board which questioned its validity. This prompted a discussion between the BPBD, Red Cross, Bali Tourism Board, and police about the merits and possibility of having the government issue such a certificate. Eventually the BPBD was tasked with making inspections and issuing Natural Disaster Ready Certificates which seems to have superseded the work of Tsunami Ready. Requirements for the government issued certificate include a safe assembly point, access (with direction signs) to the assembly point, and stored water and food at the assembly point. In addition, some hotels chose to have drills to train staff members about how to evacuate guests to the assembly point. When drills are held, the guests are given advance warning and participation is optional. Some hotels have reported that guests are in favor of these drills because it assures them that the hotel is a safe and ready place to be staying. Between 2013-2017, only forty of the thousands of hotels in Bali were awarded the Natural Disaster Ready Certificate. Most of the tsunami ready hotels are larger chain hotels that require such safety measures. According to Sideman, this means that 'the government has not given full attention to this matter.' Of the thousands of hotels in Bali, 260 are classified as star (1-5 star) hotels, 1,500 as non-star hotels, and 1,750 as homestays. The cheaper homestays and non-star hotels seldom have any type of disaster readiness. It is generally the high end hotels that express interest in becoming certified. Sideman notes that if tourismdependent Bali is perceived as 'not being safe, then tourism will fail.' To facilitate preparedness, he suggests improved coordination between the Bali Tourism Board (which includes the Hotel association), the Tour Guide Association (HPI) and the Association of Recreational Parks (PUTRI).

Some multi-story hotels in Bali are readily identified as evacuation points. Two examples of hotels in tsunami vulnerable Tanjung Benoa, which straddles a narrow peninsula with no high ground, that could be considered 'tsunami ready' are the Novotel and the Grand Aston. Corporate policies of the Novotel international hotel chain requires that its hotels in Indonesia are prepared for tsunamis. Every guest room in the hotel has a brochure with a map and information about what to do in case of a fire, earthquake, medical emergency or bomb threat. This brochure is generic and not site specific to a tsunami inundation area. Also, in each room is a very noticeable large placard on the door with an evacuation map of the hotel grounds and with detailed instructions about what to do in the event of a tsunami and other emergencies. It explains that if a guest feels a strong or long lasting earthquake there may be a tsunami. Guests are told to follow the instructions announced in the hotel and on the beach by loudspeakers and megaphones. Guests are encouraged not to panic and to move to the designated assembly places in the hotel. Once gathered at the assembly points, the hotel guests are then directed 200 meters down the street to the Grand Mirage Hotel. A sign in front of the Novotel points the direction to the taller hotel. A local elementary school has arranged to use the nearby Grand Mirage and Ion Hotels for evacuations. The Elementary school children would also follow these signs.

The tsunami ready Grand Aston Hotel in Tanjung Benoa is not identified as a public gathering place, but it does have well marked signs near the beach and pool areas and on every floor in the hotel that leads guests up to the safety of the hotel rooftop above the fourth floor (see *Figure 6*). While well marked with signs, at check in guests are not informed about the meaning and use of these signs and the emergency information posted on the doors of each room of this hotel is very generic and refers only to evacuating down and out of the building for emergencies like a fire. No mention is made to evacuate up to the rooftop in the event of a tsunami threat.



Figure 6. Tsunami evacuation sign at the pool of the Grand Aston Hotel.

The island of Lombok is often referred to as an up and coming rival to Bali. It is more laid back and less congested than Bali while still offering beautiful beaches. The two main tourist destinations are the city of Kuta on the southern coast and the Gili islands off of the northwest coast. In 1977, a relatively small tsunami came ashore in Kuta. People remember the ocean turning black, easily catching stranded fish when the water first receded only to have a second wave wash out their catch, and people climbing coconut trees for safety. There were no deaths. Little action was taken after that tsunami: no signs were posted, memorials erected or inundation levels marked. The Aceh tsunami in 2004 was different. After seeing news reports of the devastation, several families in Kuta made the decision to leave their homes on the coastal plain and build new houses on the slopes of the nearby hills. Additionally, as in most parts of Indonesia, local and national disaster mitigation agencies started to act. In 2015, the BPBD put up evacuation signs and held a tsunami simulation. Local residents were recruited and compensated (20,000 rupiah or about \$2, a meal and a bottle of water) to gather on the beach and then run several hundred meters inland to the mayor's office after a siren sounded. Residents were taught that earthquakes cause tsunamis and that they should run to higher elevations for safety. Several dozen tsunami evacuation signs were posted throughout the small town. Unfortunately, the signs were posted with the simulation in mind. All of the signs in town pointed to end-of-simulation gathering points like the mayor's office, the central mosque, an elementary school and an artists' market. These gathering points were fine as a place to offer compensation and a rice lunch, but they were not in line with teaching the need to head for the hills.

When asked about the signs, some locals explained that they would go to one of the gathering points first and from there they expected that someone from the government would come with transportation to take them inland. Others were more pragmatic. When asked about the purpose and practicality of the gathering points, one father, who had built a home on the safety of the hillside, described the evacuation signs as "crazy" and noted that if they followed the signs to the gathering point "they would all die." Several merchants with evacuation signs posted nearby, also explained that they would ignore the signs and run or ride a scooter to the hills. Several government officials also mentioned that the reason the signs pointed away from the hills was that the land belonged to private developers for future resorts and they did not want people "trespassing" during evacuation drills.

While in Kuta our team held two evacuation drills. The first at Elementary School 2 showed the mixed-up futility of the signs and the reality that even school children knew that the best direction to go was up the nearby hills. The school is one of the designated gathering places so signs point first to the school and then from there the signs point to the additional gathering points further into the center of the coastal plain. When presented with the need to quickly get to an elevation of 20 meters, all of the fourth and fifth graders knew to run westward, against the signs, to the nearby hills only a few hundred meters away.

The small city of Pemenang and its port of Bangsal are the ferry departure point to the Gili Islands. In 2012 a TES was built on the outskirts of the town (see *Figure 7*). The national governmental disaster management agency (BNPB Badan Nasional Penanggulangan Bencana) made the decision to build the shelter in part to provide protection for tourists. Curiously, most tourists only pass through Pemenang en route to the Gili Islands. Additionally, there are hills to the south of town that could provide tsunami refuge. Sirens have yet to be installed.



Figure 7. Temporary Evacuation Shelter in Pemenang

Soon after being built, the local BPBD held the first and only evacuation drill to the TES in which locals were paid to participate. Locals have mixed feelings about the building. Interviews with locals indicated that many in town attribute the construction of the TES to corruption and collusion that enriched some but made no sense to most. Some feel that the Gili Islands will stop a tsunami from reaching the town thus rendering such a structure as useless. A local non-profit (Pasir Putih) led a crusade to use the building for community activities as a way of helping suspicious locals become more accepting of the building and thus more willing to use it for evacuations. In 2016 the first annual Bangsal Meggawe Festival was held at several locations around town including the TES. The festival included cultural performances, activities, cinema showings and artists in residence. Many of those artists were then recruited to decorate the TES which they renamed Taman Evakuasi Seniman (evacuation park artists) which still uses the same acronym. Upbeat murals now decorate the ramps and the top two floors of the structure. Included in the decorations are dozens of yellow ducks leading the way up the ramps; a humorous slogan encouraging people to open their umbrellas before being rolled up by the waves, and a mural of clenched fists stating, "Together we our strong." Another mural covers the whole floor of the top level and is easily seen from the air. It depicts a person with raised arms floating on half of an avocado with the large words "I'M HERE" written to the side. When not in use for the artist festival local children use the structure to play badminton in the open atrium and for athletic training on the top floor. Sadly, the 2018 earthquake in Lombok rendered the TES unsafe and destroyed the colorful main mosque in the center of town.

The island of Sumba is unique among most of the major islands of Indonesia in that it is not volcanic. It is an uplifted slab of limestone with low lying hills and limited fertility. It sits astride the Java Trench and is as prone to earthquakes and tsunamis as the other islands along Indonesia's southern perimeter. Sumba is also the only Christian majority island included in our survey with a mix of Protestants and Catholics. Sumba and the other eastern islands of Indonesia are less developed and less populated compared to Java and Bali. They do not receive as much access to government resources and programs.

In our many classroom presentations and from survey results and interviews it became evident that most inhabitants of Sumba do not think their island is susceptible to tsunamis. This stems in part from the lack of worrisome volcances which are constant reminders of subducting plates below and a limited awareness of the island's seismic history in which there have been 21 tsunamis in the past 388 years beginning in 1629 (an average of one tsunami every 18 years). The most recent tsunami was in 1977 and before that 1938. None of these recorded tsunamis were major. Most of them originated from earthquakes along lesser faults to the north or east. The lack of tsunamis from the south suggests that there is considerable buildup of pressure along the section of Java Trench to the south of Sumba. The lack of any heavily destructive tsunamis in the past 400 years may explain why there is a local perception that Sumba is tsunami free and may also explain why Sumba, unlike Java, seems to have no folk tales or guardian deities associated with tsunamis or the sea to serve as a reminder of past disasters. Locals commonly expressed sentiments such as "tsunamis don't come here, that happens in Aceh." Sumba is the island furthest east and away from Sumatra of all our surveyed islands.

When visiting with local BPBD officials we were told that they were allocated a small budget from the BNPB (national agency) for posting evacuation signs. The budget was based on previous reporting of natural disasters, most of which were landslides during the rainy season. Signs were therefore posted in the areas where landslides have occurred leaving coastal tsunami areas with limited signage. There was no evidence of municipalities on other islands having to choose which disasters to focus on because of limited budgets. The focus on landslides has meant that in the rural outskirts of Waingapu, some of the evacuation signs (using the standard tsunami wave) point out into the rice paddies—which provide safety from landslides instead of up onto the surrounding hills which provide safety from tsunamis.

The undulating physical geography of Waingapu makes the establishment of evacuation routes and gathering points much more problematic than most coastal towns where it was easy to see and know what was high and what was not. On one day of field work we were discouraged to observe that there were no identified evacuation routes leading from the port area to safe areas. There were also no hills within sight. There was however a gradual rise in elevation leading away from the port. At the top of the rise stood a large mosque with a second story. When we inquired at the mosque as a potential evacuation site we were told that there had never been any thought of using the mosque and that a better option would be to evacuate down the rise across a river bottom and then up another rise to the government complex to safety. That rise was also a safe place, but the distance, especially for those coming from the port was too far outside the evacuation window to individuals to reach in safety.

In Waingapu we met with about two dozen local disaster officials to share our findings. We showed a map of the city that highlighted the inundation zone (see *Figure 8*). We pointed out the few evacuation signs posts that confusingly point in opposite directions. We then recommended evacuation sites (red stars), including the mosque up the incline from the harbor, that were in safer locations than the currently identified gathering places. Laying out and marking routes to these evacuation sites and then holding evacuation drills along the routes will help the people of Waingapu to be ready for a future tsunami.



Figure 8. Waingapu inundation map by Bryce Berrett.

Conclusion

Our survey results demonstrate a great need for communicating tsunami risk and efficacy messages throughout Indonesia. Java, Bali, and Lombok tsunami susceptibility perceptions fell, on average, between *neutral* and *agree* while average tsunami susceptibility perceptions for Sumba fell between *disagree* and *neutral*. Tsunami risk and efficacy perceptions varied substantially by island suggesting the importance of needs assessments and culturally-tailored interventions when planning educational campaigns. Proximity to Aceh, funding for safer evacuation routes, lack of tall structures for evacuation, and varying terrains were shown to impact threat and efficacy perceptions depending on location and these factors must be addressed in localized initiatives.

Survey participants overall preferred to be warned by siren and TV over natural warning signs (e.g., ground shaking, receding ocean). There was also an overall preference to "order or alert from an authority" over "natural warning signs" in terms of evacuation circumstance. The history of delays, failures of EWS, and reluctance of local leaders to prompt community evacuation (since they believe they may be shamed if a tsunami does not come) necessitates a shift in attitude in terms of recognizing natural warning signs and immediately self-evacuating. This key message is included in the 20/20/20 campaign. The majority of participants said that they would evacuate uphill, followed by inland, followed by climbing the stairs of a tall building. Some of our research areas did not have hills or sufficiently tall buildings and we recommend TES are built in these areas as structural mitigation measures. Conservation of natural vegetative barriers is also important in many of the high-tourist locations where mangrove forests are cleared for tourist beaches and coral reefs are being depleted.

Since 2004, many coastal communities on the southern rim of Indonesia have made significant improvements to prepare residents for future tsunami disasters. National and local disaster mitigation agencies have installed tsunami warning systems (some of which no longer work), posted evacuation and tsunami inundation signs, identified safe gathering areas, built evacuation shelters, identified other tsunami ready evacuation structures, and conducted evacuation drills. Additionally, some locales have distributed tsunami maps showing routes and inundation zones, placed evacuation directions in hotels, and built tsunami memorials as a reminder of what has once happened and what might again happen.

In spite of these efforts there are still many who believe they live in a safe area or think that the government will be able to warn and transport them to safety in time. Efforts at all levels of governance need to continue to foster tsunami awareness.. Each new cohort of school children needs to regularly practice evacuation drills and be taught the principles of 20/20/20. Complacent adults should formulate or adjust plans so that they know how to recognize tsunami signs, where to go for safety and the time frame of how long it will take to reach a safe place. Additionally, more funding should be made available to make sure each village and city has evacuation routes and gathering places identified and appropriate signage posted to show the way. Future actions could include posting tsunami high water markers/signs along the coast, making sure that tsunami warning systems are installed and kept working, and developing rapid alert systems that are connected to increasingly common hand phones.

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Reducing Child Mortality in Sierra Leone with a Sustainable Diagnostics Device for Sickle Cell Disease

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Abstract

Sickle cell disease (SCD) is a genetic blood disorder that affects more than 250 million people globally (Ilesanmi, 2010). The disease arises from an abnormal variant of hemoglobin in the bloodstream, which causes healthy red blood cells to assume a sickle shape. Aggregations of these atypical blood cells can inhibit circulation and lead to many health complications that can become fatal if left untreated. When the disease reached the United States during the 20th century, there were sufficient resources for the innovation of advanced diagnostic procedures to identify SCD in its early stages. However, low-to-middle income countries (LMICs) in Sub-Saharan Africa lack the means to effectively cope with the disease, thus demonstrating the healthcare inequalities between LMICs and developed countries. Between 50-90% of SCDaffected individuals in this region die before the age of 5, accounting for over half of the global SCD-related deaths in children under 5 (Tshilolo, 2019). To address this health crisis, the Lehigh University Sickle Cell Diagnostics team (SicklED) is developing a low-cost, point-of-care screening device for SCD that is designed for implementation as a neonatal standard operating procedure (SOP) in local hospitals. Because the lateral flow device is paper-based, its fabrication is sustainable and easily constructible without advanced medical training. With help from sponsors and the team's established network of healthcare and social workers in Sierra Leone, SickIED's plan is to assist the efforts present in Sub-Saharan Africa to help raise public awareness of the importance of healthcare and definitively diagnose SCD in these regions.

Keywords: sickle cell disease, lateral flow device, test strips, sustainable global health, low-cost diagnostic, LMIC

Purpose

Universal screening and early intervention programs for SCD are crucial to preventing patient fatality, as they are proven to increase the life expectancy of those who have the disease (Kanter, 2015). However, LMICs such as Sierra Leone lack the resources and knowledge to definitively test for SCD. While primary diagnostic methods used in high resource countries include Isoelectric Focusing (IEF) and High-Performance Liquid Chromatography (HPLC), these technologies are costly, limited to a lab, and require a continuous reliable supply of electricity (Ilesanmi, 2010), thus making them unfeasible in LMICs. Additionally, Sierra Leone is one of the least developed countries worldwide, with uneven distribution of resources throughout the country (Caviglia, 2021). The vast majority of hospitals are concentrated in the country's capital, Freetown, thus preventing

individuals living in rural communities from access to healthcare. Furthermore, the poor service quality and lack of skilled medical staff contribute toincreasing out-of-pocket expenses, as this high demand towards a low supply exacerbates the issue and skyrockets prices (Caviglia, 2021). With 53% of the population living below the poverty income line of \$1.25 U.S. dollars a day, medical care is not feasible unless it is cost-effective (World Food). Therefore, with an already existing lack of education and awarenessabout the disease, there are scarce opportunities for SCD diagnosis.

While several small-scale screening initiatives have been implemented throughout LMICs, these initiatives were time-consuming and expensive, thus making it infeasible to continue these practices in LMIC and furthering the disparity between health care between high-and low-income countries. Two such programs were initiated in Angola and Uganda, and involved collecting dried blood spot (DBS) samples from newborns in high-risk areas, and sending them to centralized laboratories for isoelectric focusing analysis (Mvundura, 2019).

These programs had costs estimated to be \$15.36 and \$9.94 per test, respectively, and the timeconsuming operations of the initiatives did not account for the need for early diagnosis of SCD. Evidently, the lack of a low-cost, point-of-care screening device in LMICs leads individuals with SCD to be left undiagnosed until they are present with clinical symptoms in late childhood, when treatments such as folic acid penicillin prophylaxis are less effective (Italia, 2019). This makes the illness a multifaceted issue in these regions, requiring not only the innovation and implementation of an accurate screening device, but also a campaign to spread awareness about the disease and its trajectory to local communities. SickIED acknowledges each dimension of therequired solution to the problem by addressing aspects of SCD education, device cost and accessibility, and testing accuracy to advocate for sustainable global health.

The SickIED screening device provides an affordable and effective solution for SCD testing in LMIC. The paper-based test strip is designed to differentiate between individuals who have SCD, carry the sickle cell trait (SCT), or are healthy. Additionally, SickIED pushes forth aneducational campaign by informing locals of what SCD is and how early detection is crucial to increasing the life expectancy of an affected individual. With increased awareness, people in LMICs will be more inclined to use the device, thus promoting long-term healthy living. These plans have been made possible through the connections that SickIED has been fostering with in- country organizations such as World Hope International, the Sickle Cell Carers Awareness Network, and Sickle Cell Society in Sierra Leone. This collaborative combination of screening, education, and treatment led by partnerships between SickIED and other SCD organizations, as well as local physicians, clinics, and hospitals, will promote well-being across all ages to ensure and maintain standards of healthy living in accordance with local community life. Upon success in Sierra Leone, the device will maintain sustainability through its implementation into Sierra Leone's health infrastructure through the Free Healthcare Initiative (FHCI), which provides basichealth services to pregnant women and children under five (Witter, 2016). Upon local implementation, SickIED operations will be handed off to the Sierra Leone Ministry of Health, where the device can continue to be developed and optimized further without SickIED's involvement. Successful SickIED operations have the potential to expand to other Sub-Saharan countries to improve the life quality and life expectancy of SCD-

affected individuals, thus creating value for patients, their families, and the global healthcare system overall.

Design and Approach

The SickIED device design meets standards of accuracy, sustainability, affordability, andportability such that unnecessary costs are minimized and accurate results are guaranteed. In alignment with the sustainable development goals (SDG) of the United Nations (UN), the SickIED diagnostic device will reduce financial burden and healthcare inequality by improving long-term health outcomes for SCD-affected individuals. While SickIED's primary focus is to lower the SCD-related child mortality rate in Sierra Leone and other LMICs, the concentrations and volumes of the antibodies in the SickIED screening device are designed to be manipulated and optimized for use with varying forms and concentrations of hemoglobin across all age ranges. Thus, the test strip is designed to have a wide dynamic range between infants and adults, with the ability to distinguish between individuals who have SCD, SCT, and are healthy.

Beginning with screening and diagnosis of diseases, SickIED promotes the well-being of individuals at all ages and allows for the administration of proper treatment. This will significantly reduce the number of preventable deaths and promote good health as outlined in SDG 3. Additionally, the SickIED implementation phase, which includes collaboration with multiple SCD advocacy networks in Sierra Leone, demonstrates alignment with SDG 10 because of its commitment to reducing global healthcare inequalities.

The SickIED test strip employs simplified immunoassay techniques with small quantities of reagent, thus ensuring accurate results without compromising device affordability. Modeled after the common pregnancy test, the structure of the SickIED test strip is built based on a lateralflow sandwich assay (Figure 1), where an antigen-antibody complex with conjugated beads allows for control or test lines to appear. Lateral flow immunoassays are largely employed in point-of-care settings due to their simplicity and the minimal resources required (Easthope, 2021), the SickIED device adopted its paper-based design as a lateral flow assay with an assembly that does not require advanced medical training. Thus, the SickIED test strip will allow for increased SCD diagnostics accessibility within local health clinics in Sierra Leone and other LMICs, given that local healthcare workers will be able to construct and administer the SickIED device without more than an information manual for both purposes. In this way, a method for SCD diagnostics will become widely available and accessible in LMICs.



Figure 1: The sandwich structure formation

Blue latex beads conjugated with an anti-HbA/ anti-HbS antibody detect the HbA/HBS analyte in the sample and create visibletest lines. The blue test lines then indicate whether the patient has normal blood, SCD, or sickle cell trait.

The SicklED E-junction lateral flow test strip is constructed from four main components: a nitrocellulose membrane, an adhesive polystyrene backing card, a CF5 absorbent pad, and conjugate release pad (Figure 2). The nitrocellulose membrane of the test strip contains the printed antibody lines, which include a control line and a test line for each antigen in the sample deposited on the test strip. The paper-based absorbent pad (5mm x 15mm) is attached on the end, nearest to the antibody lines, as the sample is located at the ends of each arm where the sample will be applied. The backing card is beneath the nitrocellulose membrane, absorbent pad, and sample pads, providing the device with structure and support. These materials each have a paper base, thus providing for the sustainable qualities of the SicklED test strip, which range from its availability to its biodegradability. While lateral flow devices that are based on polymer microfabrication lack environmental qualities and will likely contribute to the accumulation of plastics in the environment (Saidykhan, 2021), the SicklED device avoids this issue, thus providing a rapid, affordable, and environmentally sustainable method for SCD diagnosis.

Paper is not only manufactured locally in an abundance of locations around the world, but is often available in various engineered forms, giving it a range of material properties. Givenits paper base, SickIED test strip administration does not rely on an active pump or external power source, and instead relies on the advantageous capillary effects of paper to carry the necessary reagents up the strip for diagnosis (Chiang, 2019). This is an essential aspect of the device, considering that many health clinics in sub-Saharan Africa do not have reliable access toelectricity. Similarly, the small size of the SickIED test strips and their requirement of only smallvolumes of samples and reagents for diagnosis makes the device easily distributable, thus contributing to the sustainable cost and local accessibility of the SickIED test strip. With paper- based microfluidics that benefit the environment in Sierra Leone, SickIED serves a valuable purpose in LMICs with regard to healthy and sustainable living.



Figure 2: E-junction test strip assembly.

The E-junction design incorporates three sample pads ($5mm \times 10mm$), attached 5mm apart and positioned perpendicular to the nitrocellulose membrane ($5mm \times 35 mm$) with clear laboratory tape. The sample pads and absorbent pads overlap the nitrocellulose membrane by 2mm, respectively. The nitrocellulose membrane facilitates capillary action such that the analyte, wash

buffer, and beads are pulled up to the absorbent pad, which increases the volume drawn and allows for the sample to fully travel to the test lines. The control, HbA, and HbS antibodies are printed right below the absorbent pad.

Translation of SicklED's technology into practice will be conducted through the LehighUniversity Office of Creative Inquiry and its close collaborations with clinics in Sierra Leone. The SicklED team has recently received Institutional Review Board (IRB) approval from the Sierra Leonean Pharmacy Board Control to conduct alpha testing groundwork and is in the process of receiving IRB approval from Lehigh University. Once the device reaches clinical testing stages, SicklED will work towards district, regional, and national care system approvals before clinical and hospital implementation. In-country partnerships and mass manufacturing byWancheng Bioelectron Co. is anticipated to supply distribution to hospital and physician health units; the team will then work with World Hope International and local health ministries to distribute materials. In-country partnerships and mass-manufacturing by Wancheng Bioelectron Co. is anticipated to supply distribution to hospital health units; the team will thenwork with World Hope International and physician health units; the team will thenwork with World Hope International and physician health units; the team will thenwork with World Hope International and physician health units; the team will thenwork with World Hope International and local health units; the team will thenwork with World Hope International and local health units; the team will thenwork with World Hope International and local health units; the team will thenwork with World Hope International and local health units; the team will thenwork with World Hope International and local health units; the team will thenwork with World Hope International and local health units; the team will thenwork with World Hope International and local health ministries to distribute materials. Upon successful implementation in local healthcare clinics, SicklED operational management will be given to the Sierra Leone Ministry of Health, which will continue to sustain and build upon progress.

Aside from diagnosis, education and treatment are essential components of the SickIED venture that contribute to its alignment with the SDGs. Raising awareness of SCD symptoms in Sierra Leonean communities and incorporating the screening device into the FHCI will allow for the SickIED to become integrated into local infrastructure, thus definitively promoting a reduction in healthcare inequities between LMICs and developed countries. In-country healthcare providers will be trained to operate the test strip and teach other clinicians, thus promoting widespread free and easy access to screening. Once patients are diagnosed, they will be connected to receive proper treatment at a nearby hospital. These elements contribute to increasing the likelihood of life quality and life expectancy for children and adults affected by SCD. As more information about the experience of SCD patients in LMIC is collected, the SickIED education campaign will be further developed to address additional needs. This knowledge will further increase the long-term sustainability of the SickIED device as it will improve the understanding of the need to be screened.

SicklED operates under the strong belief that early detection of SCD is crucial to proper treatment and a healthy life. Beyond testing, the team strives to collaboratively contribute to educational efforts in LMIC, beginning in Sierra Leone. The connections that SicklED has fostered with incountry organizations such as World Hope International, Sickle Cell Carers Awareness Network, and Sickle Cell Society in Sierra Leone will allow for community membersto be properly educated on the effects of the disease and subsequently connected to affordable treatment options including folic acid and penicillin prophylaxis (Italia, M. et al 2019). This collaborative combination of screening, education, and treatment led by partnerships between SicklED and other SCD organizations will promote well-being across all ages and ultimately help reduce the healthcare inequalities present between high and low income countries.

Findings

Findings by the team involve multiple aspects of laboratory and sociodemographic research results, which influenced changes in the device configuration and the approach that SickIED will take in implementation. In designing the test strip, SickIED team members evaluated antibodies which respectively target HbA and HbS in varying combinations of volume and concentration to maximize test line intensities of the device and improve dynamic range of the device. The dynamic range of the device is important to ensure that the SickIED device is usable across a wide variety of individuals, while test line intensity, indicated by the darkness of the blue lines on the strip, visibly demonstrates the specific detection of HbA and HbS by the antibodies, despite varying concentrations of antigen. These two design factors were found as important metrics of the SickIED device diagnostic ability as they affect the extent to which the use of the test strip can impact the healthcare community.

Evaluation of device performance was performed using straight-line test strips dipped into wells of analyte, wash buffer, and conjugated beads. SickIED utilizes two specific capture antibodies, antibody HbA and antibody HbS, from Rockland Antibodies and Assays Inc. to help form the antigen-antibody complex on the test strip with purified antigens acquired from Sigma-Aldrich. Quantification of the test line intensities involved the use of ImageJ software to analyzeand compare test line intensities from multiple test strips. Once a test strip was completely developed, images were taken under uniform lighting and with consistent camera settings to minimize variation in image quality. ImageJ subsequently served to standardize the intensity andcreate an equal platform for comparison. Following a phase of experimentation with the test strips, a predetermined background intensity value is found from an unused test strip and is usedas a baseline for comparison when ascertaining test line intensity values for each test line. The background value is then subtracted from the test line value, and this computed intensity is then compared between remaining developed test strips.

However, initial results (Figure 3a) showed low intensity values, which is an indication of crossreactivity between the test line and the antibodies placed on the strip. Hence, recent efforts in the lab have focused on optimizing the biofunctionality of the test strip and finding the most efficient buffer to reduce cross reactions, which helps to improve sensitivity and specificity. Sensitivity and specificity are metrics of the device's dynamic range, thus allowing for more widespread detection of SCD and equal access to the device by diverse individuals. To this effect, an aspect of recent laboratory findings included the balance in concentrations which minimize cross-reactivity between antibody-antigen complexes on the test strip.

After varying the concentrations of different blocking agents in the running buffer, SickIED has determined that the combination of 2.5% nonfat dairy milk (NFDM) diluted in phosphate-buffered saline (PBS) and Tween-20 efficiently minimize antigens from binding to the antibodies spotted on the membrane nonspecifically and to decrease background noise. Thevolume of beads on the strip and printed antibody concentrations were also optimized, reducing the amount of beads from 2uL to 1uL to reduce nonspecific binding. The intensities of the test lines with 1uL remain visible with 0.2mg/mL (20% diluted) anti-HbA, whereas with 0.2mg/mL(20% diluted) anti-HbS, the test

line was difficult to visualize therefore the HbS test line will remain at 1mg/mL (100%) anti-HbS undiluted.

The SickIED device is currently able to identify purified hemoglobin-HbA and hemoglobin-HbS. The antigen binds specifically to the printed HbA/HbS test line antibody; however, the future optimization of the device will include further minimization of the test line antibody interactions, quality control of temperature conditions and storage life-span of the buffers. Furthermore, clinical testing of the device using whole blood samples will be carried outsuch that the SickIED device will be run with healthy, SCD, and SCT whole blood samples.

Each diagnosis will be compared against the gold standard (HPLC/IEF) to determine a false positive/negative statistic. Initial clinical testing will be completed within the lab using obtained blood samples from the local hospital. Following successful device results from in lab testing, clinical testing will be carried out in the field. Using connections, developed though World Hope International and the Sickle Cell Cares Awareness Network in Sierra Leone (SCCAN), the device will be run on confirmed SCD and SCT individuals to further confirm device accuracy and ensure device usability in a LMIC setting.

To facilitate transport of materials for fieldwork, SickIED adapted the running buffer used on the test strips to carry antigen up the device arms; thus leading to more findings with regards to the buffer's shelf life. To prepare for travel, the team stored the nonfat dairy milk (NFDM) powder separately from the liquid component of the buffer, thereby allowing for longershelf life, as the NFDM usually aggregates into clumps, making the buffer ineffective during therunning of the strip. The buffer is stored at room temperature; therefore, no electricity for refrigeration is required, making the test strip a portable and sustainable option for SCD diagnosis. The SickIED laboratory stores reagents and conducts experiments with temperature and humidity conditions like those of Sierra Leone to replicate the in-country environment and optimize development.





(a) Experimental straight test strip results; 20mg/mL of HbA/HbS concentration resulted in minimal cross-reactivity on the test strip. (b) ImageJ quantification of test line intensities presenting a promising result of lowlevel of cross reactivity.

Additional previous work in the SickIED laboratory utilized enzyme-linked immunosorbent assays (ELISA) to confirm antibody bead conjugation; however, ELISA was labor-intensive, expensive

and was highly variable. Successful bead conjugation is now confirmed through the development of the control and test line intensities. It was evident that theaspects of the previous design of our lateral flow strip could potentially infringe on current patents; therefore, SicklED research into patents led to findings of current SCD diagnostic methods on the market. For example, a prominent US patent that exists for the device is a lateralflow immunoassay rapid test detecting the presence of hemoglobin A, C, and S (US20160116489A1). In this patent, the claims protect specific antibodies used for the detection of these hemoglobin types and their amino acid sequences, immunoassays using these antibodies (including competitive and noncompetitive immunoassays), and a lateral flow device using theseantibodies.

In further evaluating current SCD devices on the market, several substantially equivalentSCT and SCD diagnostic devices were found. Analogous devices, such as SickleSCAN, are classified as a class II device and serve as a predicate example for substantial equivalency.

Another device that can qualify as being substantially equivalent is Arlington Scientific, Inc.'s Sickle Cell Test Kit, found in the FDA 510(k) database by the reference number K960947. Thiskit uses a number of reagents to detect the presence of HbA or HbS hemoglobin, but does not differentiate between SCD and SCT. The SICKLEDEX kit, located in the FDA 510(k) databaseby reference number K013316, is also approved by the FDA and may be another potential device that can qualify as substantially equivalent to as the device uses a number of reagents to differentiate between SC blood and normal blood by solubility differences. Finally, SicklED identified a CE-marked device that does not have FDA approval called HemoTypesSC. This device is also a lateral flow test and differentiates between HbA, HbS and HbC by mixing the blood samples with reagent before depositing them onto the strip.

With this research into account, the SickIED team began experimentation with unique test strip configurations to prevent contravention of any patents in place. Before landing on the E-junction geometry, SickIED considered the T-junction and Y-junction test strips, and experimentation with these configurations led to the finding of the "hook effect", which occurs when the antigen is present in very high amounts of concentration, blocking all the capture and detection antibody binding sites. This obstructs the sandwich structure of the device mechanism from forming, consequently revealing no visible line and producing false negatives and false positives. In the case of the "hook effect", the blood sample is directly deposited onto the test strip, but the exact concentration of the hemoglobin in a single drop of blood is unknown, so the oversaturation phenomenon of the hook effect could inhibit the intensities of the test lines that form. The E-junction configuration of the test strip helps minimize this occurrence, with the incorporation of two wash steps which helps reduce the concentration of antigen present on the test strip.

SickIED's collaboration with World Hope International (WHI), a multinational, nonprofit organization dedicated to alleviating global poverty and improving global health, has allowed the team to access networking opportunities within Sierra Leone during the developmental phase of the device. For example, through connections with WHI, SickIED met with other SCD advocacy networks in Sierra Leone which provided access to local healthcare clinics and patients. Specifically, WHI's network team has allowed for connection with the Sickle Cell Society, the

Sickle Cell Cares Awareness Network (SCAAN), as well as the Masanga Hospital. These organizations and individuals identified the pressing need for a low-cost screening deviceand expressed an interest in SicklED's proposed solution. In this way, SicklED has grown in ways that are truly beneficial for the local community. Metrics of success in this regard are the direct feedback from the local health workers who SicklED works with to administer the test.

During each fieldwork cycle, the team continues to explore implementation strategies that follow the FHCI of Sierra Leone which provides free healthcare for children and nursing mothers. The plan for this exploration is to administer diagnoses to children before the age of 5 years or neonatal screening. Through this screening program, children will receive preventative treatments early and begin practicing methods of symptom management at a young age, which has been proven to be beneficial in reducing the intensity of SCD symptoms.

Research Limitations/Implications

The lack of community understanding in Sierra Leone with regards to preventative medicine is one of the primary difficulties of improving healthcare in local, non-urban areas (Rahimy et al., 2009). Parental understanding, voluntary participation, and informed consent are instrumental to the success of projects intended to reduce SCD burden. Because there are only a small number of newborn screening (NBS) programs in Sierra Leone, many parents are skeptical when informed that their seemingly healthy infant has SCD. It is increasingly more difficult to spread awareness about SCD diagnosis, considering the stigma that surrounds healthcare facilities in countries like Sierra Leone. During 2019 fieldwork, a Peace Corps volunteer in Sierra Leone shared with the team that the community often considers hospitals to be "the place where you go to die," indicating that healthcare is only sought out in times of need, instead of forpreventative measures. As per these shared beliefs, many individuals in local communities refuse preventative treatments due to their lack of understanding about the long-term purpose. This mindset is also reflected in follow up appointments, as individuals that do seek treatment often do not return for subsequent visits (Kachimanga et al., 2021). As a result of this lack of educational awareness about the healthcare system, it is difficult for physicians to hold their patients accountable. There is a lack of structure in healthcare, as patients do not recognize the importance of follow-up treatments, and clinics often have scarce resources that limit the amount of days they can consistently remain open. The negative stigma surrounding the healthcare system has also been found to apply to the specific illness that the patient suffers from. For example, when SickIED team members conducted fieldwork in 2019 and visited a local clinic, one of the maternal and child health aids expressed that, "If someone has sickle cell, they tie them up and tie them down because they believe the devil is inside them... so they don't come here." These stigmas and misconceptions about SCD in the Sierra Leonean community prevent locals from going to the clinic. This underscores the importance of educational efforts on NBS and SCD in order to increase public awareness and combat the stigma that leads community members to put their lives at risk by avoiding healthcare facilities despite their clear need.

"Brain drain," or the departure of educated healthcare workers to countries with higher compensation (Merriam Webster Dictionary), has also been a challenge to third-world countries

when it comes to improving healthcare operations. The problem is rooted in lower compensation for medical technologists and medical doctors in Sierra Leone, where they only make a monthly income of approximately \$659 and \$1370, respectively. Meanwhile, the same professions can earn an income that exceeds \$5,850 and \$24,500 per month in other countries. As educated workers voluntarily depart the region, citizens face diminished resources and personnel required for conducting intensive blood tests. There also exists a scarcity of resources for advanced blood work procedures in Sierra Leone and other Sub-Saharan African countries. Companies such as LabCorp and Quest Diagnostics in the United States are responsible for running blood tests that diagnose for SCD, and prices range from \$50 to \$100. As follows, healthcare providers face a financial burden to obtain the diagnostic tools needed to ascertain early intervention, an instrumental step to preventing such elevated childhood mortality rates. This creates a need for asimple, yet affordable, diagnostic tool that can be rapidly utilized for early detection. The SickIED screening device is easy to assemble and operate, so it's feasible for current healthcare workers in the system to readily understand the mechanism and learn how to use it. While successful implementation of the device in Sierra Leone for early SCD diagnosis can help lower the staggering mortality rate, the most important aspect of the procedure is making sure that patients who test positive have access to treatment and support that they need. These patients arenot guaranteed to seek out necessary treatment post-diagnosis - however, education and collaboration with SickIED can encourage them to do so. Patient attendance needs to be advocated for; keeping electronic records to track the patients' health history will help generate a more structured and organized plan of care.

NBS benefits to patient outcomes have been proven in many regions of Sub-Saharan Africa. Successful implementation of NBS in Angola, with an SCD clinic established at the National Children's Hospital in the capital city of Luanda, serves as evidence of success, as approximately 1000 patients are seen there annually (Therell et al., 2020). As follows, infants with abnormal FS or FSC patterns were enrolled in a newborn clinic (McGann et al., 2020). During the first clinical visit, all newborns received medication, such as the first dose of the 13- valent pneumococcal conjugate vaccine (PCV-13, Pfizer, Inc.), an insecticide-treated mosquito bed net for malaria prophylaxis, and initiated Penicillin prophylaxis, as well as comprehensive sickle cell education. As a result, the calculated first-year mortality rate for babies with SCD compared favorably to Angola's national initial mortality rate, where 3.6% of enrolled infants have died during the followup period. According to this aforementioned success, our initiative of promoting NBS as well as serving SCD education to the broader community yields a promising outcome to combat the SCD burden in Sierra Leone. At the first and subsequent clinicvisit, families were educated in the warning signs of emergency complications (fever, pallor, splenomegaly), and were instructed to seek emergency care if they noted any of the signs. The majority of the families did seek care as instructed. However, gaps in the medical system and the lack of awareness among Angolan healthcare providers prevented these children from receiving appropriate and timely care.

A study from 2015 on cost-effective analysis reveals that the NBS program in Angola is costeffective; however, the downstream medical costs, including acute care were not included in the report (Therell et al., 2020). The screening costs included supplies for sample collection, maternity nurses labor for specimen collection, transport of samples to the central laboratory, and laboratory costs for personnel to perform isoelectric focusing on all samples. SickIED aims to eliminate the demanding cost of isoelectric technology through the point-of-care approach.

SickIED's long-term goals aim to screen all newborns for SCD while also spreading awarenessof the effects of SCD. These factors will depend on strengthening the communities' positive attitudes towards the idea of diagnosing SCD. SickIED success will not be labeled by the completion of the diagnostic device, but through ensuring that the diagnostic device is implemented in LMICs followed by the receival of treatments to those in need.

Value

The SickIED effort towards implementation of the diagnostic device has significant value with regards to reducing inequities in healthcare on a global level. It is understood that diagnosisis merely the first step towards improving the life quality of SCD subjects, and access to SCD treatment is necessary to combat the high child mortality rate in Sierra Leone and other LMIC. The multidimensional approach by SickIED to reduce child mortality in Sierra Leone requires collaboration across the board, from Western donors and funding agencies to local government, non-profit organizations, clinics, and healthcare providers at different levels in Sierra Leone.

Parallel to the SickIED lab efforts in technical development and clinical evaluation, SickIED has established connections with various healthcare sectors in Sierra Leone over time, with contributions from the Lehigh University Office of Creative Inquiry. Partners such as Dr. Cheedy Jaja, SickleSCAN and World Hope International have provided us with insight on the current local community in Sierra Leone. This deeper understanding of the environment has significantly helped us in optimizing the test strip to be as useful as possible for the environmentit will be implemented in.

The education and advocacy of SCD prevention presents value to researchers already conducting studies in Sierra Leone. In the summer of 2019, SickIED had the opportunity to validate the developing device, where the team gained a greater understanding of the device's current limitations and its usability in the field through Dr. Jaja and his medical team. He and histeam have experience with diagnosing and treating SCD in Sierra Leone due to the numerous clinics they operate in. He has provided numerous resources that were crucial to SickIED development.

After lab validation of the diagnostic device in the US using blood samples from healthy, SCT and SCD subjects, field evaluation of the diagnostic device will be carried out in collaboration with Dr. Cheedy Jaja. Dr. Jaja's research team has been investigating the feasibility of point-of-care tests (POCT) to diagnose newborns with SCD in low-resourced community healthcare settings in Sierra Leone since 2017. Specifically, within the framework of the Sierra Leone Sickle Cell Disease Data Collection Project, Dr. Jaja works to determine the best practices for the implementation and routine adoption of POCT diagnostic tools, such as SickleSCAN and HemoTypeSC across different clinical settings (including rural and urban hospitals, clinics and health care centers) by involving nurses, midwives, and health workers. His group has extensive experience screening patients with the SickleSCAN device, strong support from the Governmentof Sierra Leone, and

strong commitments from local partners (SCCAN & AMMCHC). Integral to the Sierra Leone Sickle Cell Data Collect Project is planned care management for confirmed cases, care coordination, and active patient/caregiver engagement. These are crucial steps in providing comprehensive care and tackling the vexingly high rates of infant mortality associated with SCD. SickIED's partnerships with organizations rich in clinical experience involving POCT diagnostics will be leveraged to translate the proposed device for utilization. Through developing the screening device in parallel with the translational research of Dr. Jaja's team in the implementation of POCT for SCD screening, especially the effort with newborn screening, the operation and performance specifics of the device will evolve with and be optimized for proper settings to facilitate downstream wide adoption.

After successful implementation on a small scale, widespread implementation throughoutSierra Leone and other LMICs will be pursued. Widespread implementation of the diagnostic device will be in conjunction with the development of infrastructure to treat diagnosed SCD individuals. In addition to the collaboration with Dr. Jaja, SickIED has sought out continuous feedback on device development from partners in Sierra Leone. Partner relationships were formed during the initial visit (August, 2019) to Sierra Leone to distinguish developmental frameworks for the device. The SCCAN and the Sickle Cell Society allowed SickIED access to patients and local healthcare workers who provided insight with regards to the current screening situation as well as the socioeconomic and demographic impact on individual's outcome. Mutualcollaboration between the groups is beneficial to each party as we all share the same interest of lowering the high mortality rate of SCD disease in Sierra Leone. While SCANN and Sickle Cell Society provide us with information on the social aspects of SickIED, we help solve the problemat its root with a technical device. With continuation of SickIED partnerships, the goal of lowering mortality while providing necessary treatments to those in need will be feastable. Upon implementation, the device will be an asset to these two organizations and their SCD diagnosis and treatment facilities.

The SickIED device will be optimized to be affordable for clinical implementation in lowresource areas that are highly affected by SCD. The screening device is capable of sustaining functionality without the usage of electricity or large equipment currently required for diagnosis. The lateral flow technology combined with the geometry of the test strip eliminates the cost of reagents. Affordability is important in LMICs, such as Sierra Leone, due to the health inequities present. Families in Sierra Leone have limited access to resources due to their income, which makes it difficult for them to prioritize health as a concern. Due to the current high financial costs of healthcare, individuals tend to invest their financial resources into other concerns such asfood, clean water, and housing. However, the World Health Organization's ASSURED framework defines the most suitable screening devices for use in LMICs as affordable, sensitive, specific, user-friendly, rapid and robust, equipment-free, and deliverable to end-users (Kosack). Therefore, the application of the lateral flow mechanism represents the ability to adapt healthcaretechnology such that inequalities such as cost and accessibility within LMICs due to lack of resources may be alleviated.

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Can just any Country Achieve UHC?: Lessons from Different Health Systems

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Abstract

The UN's Sustainable Development Goals-3, to ensure healthy lives and promote well-being for all at all ages, adopts Universal health coverage (UHC) as one of the targets to reduce the inequality and fight poverty. Universal Health coverage (UHC) is the aspiration of the world and the global impetus for a very long time now. Even though WHO shares a framework to achieve UHC, there is no universal way to achieve it, thus, there exists many pathways depending on the socio-economic and political issues faced by the country and yet none of the single pathway is complete in itself to sustain the coverage. Hence we see countries seek to diversify the sources of revenue by using hybrid financing models or make healthcare reforms to sustain UHC. This calls for an innovation in the ways healthcare system is financed. There are many policy levers and combination of factors that may help when implemented to achieve UHC that is inclusive and sustainable in the long-run. Pursuing UHC though is expensive, complex and definitely not easy, but it is achievable.

The study reviews the evolution of diverse health systems of 5 distinct countries (Japan, Thailand, Rwanda, Brazil and Turkey) into achieving UHC as well as draws useful lessons to attain universal coverage for India and any aspiring country from their experience.

Keywords: UHC, Universal healthcare, sustainable development goals, health systems, components of health system

Introduction

The countries in the world have wrestled with the cost benefit analysis of raising their healthcare sectors. Each time a country invests more on health, it is left with a lesser budget for other investments like infrastructure, defense etc. At the same time, better health of people is linked with more productivity and hence healthier economy. Each nation set its own constraints and priorities towards providing equitable healthcare to its people, termed as Universal health coverage (UHC). Though many countries in the world have already accepted UHC as a first concern of health system, more than half of the global population do not have access to essential health services and each year millions are getting pushed into extreme poverty because of the high health expenses (WHO and World Bank). Though improving access to quality healthcare and universal coverage is a global problem, there is no universal solution to it, given the diversity of demographics, economic history and political issues within the nation and cross countries.

The United Nation's Sustainable Development Goals-3 (SDG-3), "to ensure healthy lives and promote well-being for all at all ages", adopts UHC as one of the targets of SDG-3 to reduce the inequality and fight poverty. Strengthening the healthcare systems will not only help reach SDG-3 target of achieving UHC but also positively affect the other SDG's to reduce poverty and unemployment, ensure food security, better education, equality, inclusive societies and economic growth (ONU, 2019). The WHO defines healthcare systems as, "A health system consists of all organizations, people and actions whose primary intent is to promote, restore or maintain health." The strengthening of the health system demands holistic investments in various components of healthcare alongwith embracing reforms in these structures that talk to each other so as to create an optimal system that caters to health needs of the people. There is no standard or universal path to achieve universal health coverage, thus, many pathways and arrangements exists to achieve the basic goal of a healthcare system depending on the socio-economic and political issues faced by the country. The healthcare systems aim at constantly improving patient health, meeting patients need and ensure sustainability for the longer run. While doing so the health systems have to deal with changing demographics, technology advancement, rising cost of healthcare.

The paper proceeds with the evolution of health systems of different countries (Japan, Thailand, Rwanda, Brazil and Turkey) that have followed one of these model into attaining universal healthcare along with brief introduction of healthcare system of India. It then progresses to compare the health system of these countries based on four themes namely, health financing, healthcare reforms, care provisions and human resource. Finally, the paper concludes to draw lessons for the developing countries like India, which is taking bigger strides to achieve UHC.

Japan

Japan's population is declining owing to the stage 5 of demographic transition of the country. The ageing population is causing a significant financial burden on sustaining the healthcare cost of Bismarckian model of Japan. The first health insurance act came in 1922, which resulted in the formation of The Employees' Health Insurance Law (EHI) and Community-based Health Insurance Law (CHI). Even before the act, Japan had its private and public employee covered under some voluntary associations that were not so much of appeal to workers. After the first world-war, the poor economic situation prompted the government and industrial sectors to come up with EHI from health insurance act 1922. The act was more of an industrial policy rather than a medical one and premium were parked on income of individuals usually averaging 10%, capped at 13%. The Great Depression of 1929, hugely affected the Farming community. US being one of the biggest importer of Japan's bumper crop, the plummeting price of rice along with other agricultural product multiplied the economic problems of farmers. Japan, which was gearing up for the second world war, used this opportunity to rope in farmers to build its military. It was then decided by government to provide CHI to cover temporary workers from unorganized sector starting with farmers to fisherman to self-employed. Post second world-war, healthcare were destructed and there was a political conflict to provide health cover to unemployed and poor people that pressured the then LDP government to enact mandatory National Health Insurance (NHI) in 1958 replacing the voluntary CHI to attain equitable health care as well as to sustain his

own cabinet. Those living below poverty line enjoyed free healthcare service financed by government subsidies. The premium varied with respect to income ranging from 7.3% to 15.9%. This marked attainment of universal healthcare in Japan in 1961. Though there was UHC, people had to pay 50% copayment from their own pocket. The subsequent reforms by LDP as pressured by the socialist party reduced the copay to 30% and provided free healthcare to elderly above 70 years. This populist policy later imposed heavy financial burden on the Japanese health system. At the same time, rapidly ageing population caused increase in number of retired unemployed pool of NHI thus increasing the health expenditure paid on behalf of this population. Finally the government had to abolish the free healthcare to elderly and made some independent pools out of NHI.

The elderly health systems (EHS) act 1982 requested 10% copay from elderly above 70 years who earlier enjoyed free healthcare. This act was later modified into an independent scheme called Elderly health security act (EHCSA) in 2008. Similarly, the Long term care act (LTCA) 1997, was created as an independent insurance scheme for people with disability, chronic illness or requiring long term care treatment at 10% copay. Thus, the NHI was unburdened and Japan now has 4 mandatory independent schemes i.e. EHI, NHI, LTCA and EHCSA.

There are more than 3000 insurers in Japan that are managed by Ministry of Health and Labor Welfare (MHLW) and classified based on occupation, place of residence and age. The hospitals are predominantly private, licensed by local governments and are not for profit. The MHLW sets the uniform fee schedule to bring prices of the treatment under ambit including those under NHI and all providers must adhere to schedule. The hospitals and clinics submit the claims every month with CRROs (Claims Review and Reimbursement Organizations) chartered in every prefectures that review the claims before sanctioning it to the providers' basis fee schedule. MHLW employs database that banks all the claim data received from providers, known as National Receipt Database (NDB) so as to audit and control the cost efficiently. There is no gatekeeping system in Japan as it takes pride in featuring "free access to healthcare facilities", however, patients need to pay an additional fee to access tertiary care if they do so without a referral from primary or secondary healthcare facility.

Figure 1: Japan Health System Evolution



Thailand

Thailand is considered to have one of the most efficient UHC in the world, an outcome of a wellresearched and thoughtful policy.

The Medical Welfare scheme 1975, established by Ministry of Public Health (MPOH) marked the first major health insurance program to cover poor people to elderly, children and other unprivileged groups. The program suffered from poor funding and ineffective targeting of beneficiaries and thus, failed.

By the end of the decade, Thailand had array of insurance schemes for government employees, private employees, community health insurance for people in unorganized sectors, welfare schemes for poor, voluntary health card schemes etc. and despite its versatile approach to cover people from every strata, the country was facing issues in providing a universal care.

The careful analysis reflected some challenges and issues with the coverage schemes:

- 1. There was a difficulty in assessing the target population; some individuals were covered under two or more schemes while other few had none.
- 2. The staffs providing care were not well trained.

- 3. The voluntary nature of schemes led to adverse selection and moral hazard.
- 4. There were no proper infrastructure as facilities provided were limited and geographically not accessible to many.

Thailand ultimately realized that having a universal coverage is not the solution to achieving universal healthcare. It started building on its infrastructure which gained momentum in the late 1990's.

There were three major schemes that rolled out in this period.

The Civil Servant Medical Benefit Scheme (CSMBS) 1980, managed by Ministry of Finance (MOF) covered all the government employees and their dependents without any contribution from their salaries. The scheme is solely financed from the government budget. The beneficiaries could go to any public provider to avail services and also private providers in case of emergency.

The Social Security Scheme (SSS) 1990, replaced worker compensation scheme (1972) and covered all private employees but not their dependents and was facilitated by tripartite contribution from employee, employer as well as government to provide the mandatory cover under the social security act 1990.

The Universal care scheme (UCS) 2001, funded by general taxes covered the entire population not covered under CSMBS and SSS that is 75% of the total Thai population. It was an improved version of a very popular 30-baht scheme introduced by TRT (Thai Rak Thai) leader as an election campaign that said "30 Baht treats all diseases" to provide free healthcare to its people at just 30 baht copay. The copay was later removed to provide absolute free healthcare to people. There are no deductibles, co-sharing, copayment or limit on maximum coverage.

Thai health system focusses on primary health system, which acts as a gatekeeper to comprehensive curative and rehabilitative care thus keeping the cost under control. The providers are mostly public and reimbursed by the government. There are no insurer but managing agencies for 3 schemes i.e. the Comptroller General's Department, Ministry of Finance for CSMBS, the Social Security Office, Ministry of Labour for SSS and National Health Security Office (NHSO) for UCS. There are voluntary insurers offering same service with more choices of private hospitals.

Figure 2: Thailand Health System Evolution

	THA	ILAND			
1972 – Workmen's Compens 1975 – The Medical Welfare established by the Mo	ation Act Scheme was OPH	30 baht scher MOPH National Healt	me h Security Act 2002		
Civil Servant Medical Benefit Scheme (CSMBS) 1980 • Covers govt. employees & their dependents • 8% of total population • Non Contributory (General Taxation)	Social Security Scheme (SSS) 1990 • Covers private employees • 16% of total population • Contribution Tripartite (1.5%) & Payroll tax		Universal Coverage Scheme (UCS) 2002 • Covers those not covered by SHI or CSMBS • 76% of total population • Non Contributory (General Taxation) • Gatekeeping by PHC		
	Tha Hea	ai Health Promot alth System Rese	ion Foundation (ThaiHealth) – 2001 earch Institute (HSRI) – 1992		
 Provider 75% Public Hospitals Private for profit Hospitals 	Voluntary Insu • More choices • OOP	of Pvt Hospital	No copay No deductible No celling on max coverage		

Rwanda

Rwanda is a poor small country grappling with communicable diseases that are preventable through improved hygienic measures but in recent decades it has seen great improvements and managed to achieve universal health coverage for its people.

Following the independence in 1962, Rwanda which was still under European powers endured decades of violence, bloodshed and civil war. In 1988, Rwanda adopted the Bamako initiative as health development strategy popular among many sub-saharan nations to strengthen the equity in access to healthcare. Embracing the initiative, Rwanda decentralized the care to the district level with the development of provincial to district level health system. The whole progress was disrupted following the 1994 genocide that not only destroyed the infrastructure, equipment, personnel and the health system itself but also plagued the society with ill health and diseases.

In 1995, the government began to restructure the healthcare with the same Bamako initiative, however, the health system was severely under-resourced which affected the access as well as quality. It rolled out Community based health insurance scheme or Mutuelles de Santé (CBHI/Mutuelles) in the year 1999 in the select areas as health insurance pilots. Meanwhile, GoR also initiated health insurance plans for the Civil Servants called Rwandaise d'Assurance Maladie (RAMA) in the year 2001 followed by Military Medical Insurance scheme (MMI) in 2005 to cover military personnel. The salaried individual working in the private sector are ensured medical insurance by their employers either through private insurance companies or RAMA affliation. CBHI later quickly scaled across the country and became a national policy in the year 2004. In

the year 2004, the CBHI was made mandatory for every individual not covered under any other scheme and by 2011 the coverage rose to 91%.

Every citizen is identified in the national database based on the socio-economic category to the village level an individual belongs to. This database helps the GoR to set appropriate insurance premium for each population category. Under CBHI, healthcare centres are reimbursed on fee-for-service basis. The national database is used to categorize the beneficiary in three groups. The premium paid by different categories are different and the most poor of all, is exempted from paying the premium. The copayment is fixed at 10% of the total hospital bills. The community healthcare is the gatekeeping system in Rwandan healthcare where community healthcare workers form the first point of contact with patients. From the CHW, patients move to the Health Post or dispensary to the Health Centre to the District hospital and ultimately to the Provincial or Referral hospitals. Apart from the public sector that facilitates and manages healthcare at various levels with respect to the 'minimum package of activities', GoR has also authorized government assisted health facilities (GAHF), private providers, and quacks to join the work task force.

Rwanda has maintained its own measure of geographical accessibility to healthcare i.e. a service is said to be accessible if a patient could visit a nearest healthcare worker 'in less than 1.5 hours by walk' and with this definition, more than 85% of the population have access to healthcare service in Rwanda.

Source: (Aly et al., 2000; Jarl, 2011; USAID, 2013)



Figure 3: Sources of Funding for CBHI, 2012-13

Figure 4: Rwanda Health System Evolution



Brazil

Source: Ministry of Rwanda

Brazilian health system started officially in 1923 with the launch of social security system (SSS) for those working with private organizations. The SSS was based on mandatory contributions from both employer and employee and this system that did not cover majority of the Brazil, remained in order until the health reforms began in 1970. Though, healthcare for the people were still not considered a right, the Ministry of Health started with providing basic medical care to the people not covered under SSS.

In 1985, after the political power in Brazil was finally returned to the civilians, re- democratization brought a brand new constitution which was more inclusive of social and civil rights of people that guaranteed right to health in order to achieve universal healthcare. Brazil introduced, SUS (Sistema Único de Saúde) as a first step towards UHC that covered whole population. By the next decade, the SUS grew substantially to provide universal coverage to Brazilians.

The SUS, a national health system of the country provides free healthcare to anyone residing in the country legally including visitors. Apart from comprehensive curative and specialized care, SUS focusses on preventive care, primary care as well as mental health. In 1994, the family health strategy was introduced as a national policy to expand the primary care in SUS, while municipalities controlled the managing and delivering part of it. It presents health team comprising of a doctor, a nurse, a nursing assistant and maximum 12 CHW. Each team caters to 2000 to 4000 individuals in the population. Similar to health team, oral health team comprising of one

dentist and 1- 2 dental assistant cater to the same population size. The model is financed by federal government and its success led to the appreciable reduction in the in-patient admission.

The SUS system is decentralized, has gatekeeping mechanism and is jointly financed by tax revenues, federal and municipal contribution. The contribution rate for health expenditure as per the law is at least 15% for both Federal and Municipal level separately and 12% from the State level of their own total revenue. In 2017, the federal share was 43% of the total public healthcare expenditure while state and municipalities contributed 26% and 31% respectively.

The patients do not have to pay any premium or copay to avail health service, nevertheless, there are limited set of medications that are available under SUS. The care delivery and administration are dealt by state and municipalities. Though health is free at the point of care for the population, almost 25% Brazilian go to private healthcare centres to avail paid services with their private health plans to avoid bottlenecks to access public health centres. Many people working with private sector also receive health insurance in the form of employee welfare schemes.

Brazil spends more than 9.5% of its GDP to the healthcare of which almost 50% is the public spending. The cost of medicines that are not covered under the SUS account for one of the primary reason for ~27% of the OOP expenditure. The ever increasing copayment from private health plans is another major reason for high OOP.



Figure 5: Brazil Health System Evolution

Source:(Massuda et al., 2020)

Turkey

The history of public health in Turkey dates back to 1920's when the first minister of health brought some radical changes to healthcare system. The law on public health was created, detailed framework of public health was established along with provincial health directorates and public hygiene institute (1928). The main agency of health i.e. Ministry of Health which was constituted in the year 1920 built numune (ideal) hospitals as an example of best hospitals to guide local governments that were responsible for providing in-patient care. To deal with scarce medical staff, state government subsidized the medical education of poor students along with providing additional benefits and this led to a doubling in number of doctors with each passing decade. Medical staff working in preventive healthcare were paid better salaries than those working at other level.

However, with the passing time focus from primary care shifted to in-patient care and more hospitals were build. The healthcare facilities under different ministries and municipalities were centralized under Ministry of health. Health centres were built for villages, many vertical programs were introduced for malaria, tuberculosis etc. and few more healthcare laws were created but yet Turkish people living in the rural area had no access to even basic healthcare services. This called for the introduction of another law to socialize the healthcare services in the year 1961. Under this law, health centres were established with one doctor and allied healthcare staff per 5000 population, a health post with one midwife nurse per 2000 population. The infrastructure prolifered and by 1983, whole population was covered. In 1946, the social insurance scheme called Sosyal Sigortalar Kurumu (SSK) was launched to provide cover to the daily wage or meagre salaried workers of public sector. To provide the cover to the rest of the public employees, Turkey started Government Employee's Retirement Fund (GERF) called "Emekli Sandigi" in the year 1950. In 1971 Social Insurance Agency (Bağ-Kur) scheme started for those working in unorganized sector and self-employed. These schemes acted as a major health policy over the years and on the backdrop, UHC occupied the health agenda for several coming decades. As a temporary means in 1992, the Green Card scheme was introduced to cover all the uninsured and poor people who can certify that their income is lower than one-third of the base wage rate determined by the state. The scheme provided access to all level of care with 20% copay on pharmacy and OPD care.

Nevertheless, the effort continued to improve public health, develop a patient-centred system and attain a single universal program for the entire population. In 1993, MoH published a document outlining the framework to plan the future of health system but the reforms never got implemented because of the deep political turmoil faced by Turkey at the same time that lasted till 2002.

The new government in 2003, rolled out Health Transformation Programme to streamline the healthcare system that gained momentum by the year 2008 and all the insurance schemes were brought under a single umbrella. The, SSK, GERF, Bağ-Kur, Green Card holders, refugees and foreign individuals not covered in their home country were now under the ambit of General Health Insurance Scheme (GHIS) with effect from October 2008. In the year 2008, 94.2% of the population were officially covered by the public health insurance.

The Turkish healthcare system is financed through tax revenue, contributions from employed individuals and OOP. The healthcare is totally free for pregnant women, war veterans, tuberculosis and diabetic patients.



Figure 6: Turkey Health System Evolution

Source: (Mollahaliloglu et al., 2021; Tatar et al., 2011)

India

India has a rich heritage of traditional medicine that can be traced back to Vedic times, however, modern medicine was introduced in and evolved after 1600s with the Portuguese, French and British rule. Pre-independence, India had more than 7000 hospitals and clinics across the country (Chakrabarti, 2014). Post-independence, India prioritized the healthcare needs of its people that led to the foundation of Ministry of Health and Family welfare (MoHFW) in the year 1947. In 1946, Health Survey & Development Committee also known as Bhore Committee submitted a report that laid emphasis on integration of curative and preventive medicine at all levels healthcare, continues to be the basis of health structures of India. Around 1975, India was launching schemes aimed at improving the nutrition and health status of children in the age group of 0-6 years called as Integrated Child Development Services (ICDS) and vertical health programmes aimed at controlling the diseases like AIDS, polio, leprosy etc. The public healthcare of India took the giant stride with the launch of National Health Policy in 1983 and with that started a series of five year plans each of which determines state spending priorities for the coming five years. In 2005, National Health Mission (NHM) was started that encompasses its two Sub-Missions National Rural Health Mission (NRHM) and National Urban Health Mission (NUHM) focusing on specific needs of rural and urban India together envisaging achievement of universal access to equitable,

affordable & quality health care services that are accountable and responsive to people's needs. To revive the profound knowledge of traditional Indian systems of medicine, GOI started with Ministry of Ayurveda, Yoga, Naturopathy, Unani, Siddha, Sowa-Rigpa and Homoeopathy (Ministry of AYUSH) in the year 2014.

At central level, (MoHFW) provides administrative and technical assistance to the states in health subject along with implementation of various programs at the national level to prevent and control AIDS [National AIDS control Programme], Tuberculosis [National TB Programme (NTP)], and other major communicable diseases, promotion of indigenous systems of medicines [AYUSH], etc. There are also certain insurance programs offered at national level as a welfare schemes for poor people. The national health insurance schemes like CGHS (Central Government Health Scheme) provides comprehensive health care facilities for the Central Govt. employees and pensioners and their dependents, ESIS (Employees' State Insurance Scheme) is a multidimensional social security system tailored to provide socio-economic protection to worker population and their dependants, CHSS (Contributory Health Service Scheme), ECHS (Exservicemen Contributory Health Scheme), RELHS (Retired Employees Liberalized Health Scheme). The national welfare schemes like Rashtriya Swasthya Bima Yojana (RSBY), Aam Admi Bima Yojana (AABY), Janani Suraksha Yojana (JSY) and others aims to provide health insurance coverage for Below Poverty Line (BPL) segment of population.

The federal system of government tasks healthcare as a state subject and hence each of the 28 states and 8 union territories independently govern their public health system. This has resulted in different health insurance schemes offered by different state government that also differ in coverage, availability and access. Most of the health insurance schemes offered at state level are very similar to the ones offered at national level that has resulted in overlapping of central and certain state insurance schemes for the beneficiaries.

There has been several attempts to achieve UHC by the Government of India (GOI), the most recent being Ayushman Bharat –Pradhan Mantri Jan Arogya Yojana (AB-PMJAY- 2018) that is world's largest tax financed scheme aiming to cover socio-economically backward population that forms (approx. 50 crore beneficiaries) the bottom 40% of India's population. It provides health cover of 5 lakh rupees per family for hospitalization at any empanelled secondary or tertiary care public or private hospitals. The scheme also transforms primary healthcare by providing health and wellness centres and thus aims to offer comprehensive healthcare to all beneficiaries. However, so far only 17 crore beneficiaries have been verified from 3 years of launch of the scheme (Bhushan, 2021)

Theoretically, almost 70% of the population is covered under some form of insurance coverage including state government insurance schemes, central and state government employee insurances, private employee insurances, private individual insurances. For the remaining 30% of the 'missing middle' population, GOI has come up with Arogya Sanjeevani policy (Sarwal and Kumar, 2021) as this population segment are not poor enough to be covered under any social security scheme and not rich enough to buy private health insurance but have high odds of getting pushed into poverty because of financial hardships caused by adverse health events.

India also has a rich pool of community health insurance (CHI) schemes organized by community/NGO/cooperative society/union members where they pool funds to offset the cost of healthcare. The micro insurance regulations of 2005 offered many such schemes to buy micro-insurance products thus protecting them from catastrophic losses and promote ethical practice. The healthcare service providers are both public and private. The outpatient care is free and inpatient care is highly subsidized at public hospitals but the private health-care providers are more in demand because patients have better access to medical staff, medicines and quality healthcare. Private providers are concentrated more in urban India because of the high purchasing power of people, providing secondary and tertiary health-care services resulting in high OOP expenditure.

Figure 7 Time line of Important Events in Indian Healthcare



Table 1: Comparing Countries

	Japan	Thailand	Rwanda	Brazil	Turkey	India
Development Status	Developed country	Developing country	Least Developed country	Developing country	Developing country	Developing Country
Model of Healthcare System	Bismarck	Beveridge	NHI	Beveridge	NHI	Mixed

SDI (2017)	0.8	0.68	0.41	0.66	0.73	0.55
UHC Index (2017)	83	80	57	79	74	61
UHC adopted in the year	1961	2002	2004	1988	2003	NA

The Table: 1 shows the development status and model of different healthcare system by comparing the Socio-demographic index (SDI) and Universal health coverage (UHC) index that have strong correlation with the health outcomes. Though countries have started with some model of healthcare, few have transitioned into creating the hybrid model by absorbing features from other model so as to sustain the universal coverage.

Methodology

This study aims to study the evolution of some diverse health systems showcasing equally diverse socio-economic background into accomplishing a common goal, universal health coverage. The deliberate selection of 5 countries with UHC have been done bearing varied development status and health systems viz. Japan, Thailand, Rwanda, Brazil and Turkey. The study proposes to review the evolution of these health systems into achieving UHC and comparing these systems by focusing on four components namely health financing, healthcare reforms, care provisions and human resource, as well as drawing useful lessons to attain universal coverage for India and any aspiring country from their experience.

For the study, data collection has been done from WHO website, national repository of respective countries, and literature review of peer-reviewed journals including grey literature.

Health Financing

Japan's health financing through payroll premium contribution is quickly condensing since several decades because of the retiring population that are no longer contributing to the pool (Sakamoto et al., 2018). Hence, the country is principally relying on tax revenue and premium contribution to finance its healthcare expenditure. On the other hand Japanese are one of the highest tax payers in the world with effective top marginal tax rate being around 55% of their income (Tajika, 2018). The capping on OOP has further reduced the source of finance to the system.

The three coverage schemes of Thailand CSMBS, SSS and UCS manifest highly skewed perbeneficiary expenditure because of the poor redistribution of resources across them (Reich et al., 2016).

Rwanda too struggles with the increasing cost of care which is putting the question on sustainability of its mutuelles scheme that is funded majorly by the contribution from the beneficiaries, government subsidies and external aid. So as to understand the cost of service

delivery and ensure sustainability, Rwanda is executing a costing study with RTI, USAID and public health school (Kayonga, 2007).

Thailand being a developing country has achieved UHC with just 3.8% of GDP spending on healthcare and there are many strategies that has led to its low cost, predominant adoption of public providers being one of them. Particularly on the supply side, there is a capping on inpatient payments using DRGs, limited spending on primary care by capitation, substantial use of generic medicines etc (Hanvoravongchai, 2013).In Turkey, the alarmingly increasing unemployment rate (13.7%, 2019) is bound to hit hard the premium collection thus affecting the UHC.

Brazil and Thailand allow the breeding of private providers as well as private voluntary health insurers which has not only led to the increased private spending and OOP as high as 30% (Table 2) in Brazil is also affecting the efficiency of the public healthcare and thus raising inequity (Reich et al., 2016). Though health is free at the point of care for the population, almost 25% Brazilian go to private healthcare centres to avail paid services with their private health plans to avoid bottlenecks to access public health centres. The cost of medicines that are not covered under the SUS account for one of the primary reason for ~27% of the OOP expenditure. The ever increasing copayment from private health plans is another major reason for high OOP.

The Table 2, compares the GDP contributions of each country towards total healthcare expenditure (THE) and the public contribution to the THE. The GDP to THE is the highest with respect to Japan and Brazil but the government contribution is at the second lowest in Brazil.

Healthcare Reforms and Political Leadership

UHC goals adoption in most of the countries have shown a pattern with mostly beginning after some major socio-economic or political change (Reich et al., 2016). The UHC became the national priority following the reconstruction efforts post second world war in Japan, following a financial crisis in Thailand and Turkey, during re-democratization in Brazil and post genocide in Rwanda.

In Japan, the primary push to start UHC was to build more of a warfare state of healthy individual rather than for establishing a welfare state but the strong political commitment with concrete goals led to the accomplishment of the UHC (Ikegami, 2014). Thailand & Turkey's UHC is the result of determined commitment and leadership of its government together with sharp economic growth. (Tatar et al., 2011).

The strong social movements in Thailand accelerated UHC that was high on the political agenda and boosted the government leadership in reforming the healthcare and the same is with Brazil (Massuda et al., 2020; Reich et al., 2016). The strong commitment of the political leaders at local, district and national levels in Rwanda has led to the mobilization of population in enrolling, paying premiums and development of the universal community health insurance program (Ministry of Health, 2008).

Japan has national fee schedule that it updates twice annually which is a two-step approach of setting a global revision rate, revising pricing item by item and this has tremendously helped in containing cost by leveraging policies. Thailand has separated the healthcare purchaser and provider functions to keep accountability a priority and that resulted in creation of capable governance (Haines et al et al., 2019; Reich et al., 2016). It also demonstrates strong capacity for strategic goal setting, for the evaluation of new technologies and pharmaceutical products to be included in benefit packages. Brazil with its new leadership initiatives has started with innovative form of providing care by contracting the primary healthcare at the state level in order to improve quality and efficiency (Araujo *et al.*, 2014). To manage opposition of the UHC reforms from the interest groups, Turkey and Thailand developed strategies by creating an oversight board to understand their motivation and potential effects on the reform process (Haines et al et al., 2019; Tatar et al., 2011).

Care Provisions

Primary healthcare is fundamental in designing a cost effective and efficient system as it focusses on prevention of disease, health promotion and outpatient care is the principal means of accessing it (Attaran & Capron, 2014; Bloom, 2017). Several studies demonstrate that not only hospitalization but also outpatient care leads to impoverishment of households (Aggarwal *et al.*, 2012). The Green-card insurance scheme of Turkey introduced as part of a transition to UHC, provides comprehensive outpatient cover along with secondary and tertiary care with rigorous eligibility check, gatekeeping, cosharing to regulate and at the same time providing unrestrained access to healthcare (GÜRSOY, no date); (Tatar *et al.*, 2011).

Japan brags one of the best UHC service coverage index (83) with no gatekeeping mechanism, maximum number of hospital beds per capita (13/1000), free choice of physicians and minimum waiting time (Health & Systems, 2021). Howbeit, the same privileges provide little determent to overuse of specialized and expensive care. Japan also has the highest average length of stay (ALOS) i.e. 16.1 days per admission leading to supply side moral hazard, however, been steadily declining because of the fee schedule revision to incentivize the reduction of chronic care beds at hospitals (Sakamoto *et al.*, 2018).

In Thailand, the gatekeeping system are strictly followed care and bypassers are held liable to pay full user fees (Tangcharoensathien *et al.*, 2019).

Thailand however, exhibits clear disparities and inequity across the three schemes with respect to quality of care and access to specialized care because of the pro-rich bias, where profit hungry private facilities cater mostly to rich urban population and the poor people received care from government facilities and health centres with poor choice of providers, insufficient referrals etc.(Rodney and Hill, 2014). Nevertheless, the poor people could still have equitable access to primary health care. Similarly, Japan faces a political economy challenge by not being able to improve the fairness by creating an integrated risk pool (Reich et al., 2016). The low risk pool do not want their premium rates increased to subsidize for increasing high risk pool that is responsible for widening the premium rates. Though Thailand has relatively small aggregate of

private sector around 25% of total hospitals, this pro-rich bias has also resulted in concentration of private sector providing specialized care in the urban areas while primary care in such affluent areas remain weak (Haines et al *et al.*, 2019). The bottlenecks to access healthcare like long waiting time, poor infrastructure etc has resulted in one fourth of the population utilizing private healthcare despite having free unified health systems in Brazil (Massuda *et al.*, 2018), 2020; (Reich *et al.*, 2016).

Rwanda's strikingly distinct strength of care provision is having an efficient bottom- up and topdown mechanisms for layering the population into four different socio- economic categories with the help of the national database (Ministry of Health, 2008). This has helped in unbeatable crosssubsidisation from rich to poor using health insurance schemes while the poor are paid for by the government and development partners. The growing physician workload, lack of population trust in PHC's hindered the implementation of compulsory gatekeeping in Turkey.

The countries have witnessed a clear improvements in the health indicators, economic growth with large GDP improvements with the dawn of universal primary care service utilization as in the case of Rwanda, Thailand and Turkey ((Jarl, 2011); (Mollahaliloglu *et al.*, 2021); (Thaiprayoon and Wibulpolprasert, 2017).

Rwanda faces an ongoing challenge in engaging the members in the scheme which can be improved by providing a better quality of care.

Human Resource

In Japan, both private and public sector follow the single fee schedule which is the only cost control measure in the system that favours clinic services over hospitals (Ikegami, 2014). This also positively incentivizes the desirable workforce distribution. Thailand incentivizes healthcare workers to work in rural areas and thus ensures decent geographical distribution (Haines et al et al., 2019). A healthcare professional working in rural area are paid twice than the urban fellow. The school students are recruited from the underserved area into medical and nursing courses and made to work in their home districts after graduating. These incentives have tremendously increased (20%) the admissions of medical students (Sundararaman, 2018). In Turkey, in the framework of the HTP, certain measures to attract the healthcare workers like contract recruitment has led to the balanced geographical distribution of the physicians (Mollahaliloglu et al., 2021). The national 'prioritisation system' also takes care of the proper geographical distribution of the healthcare workers by assigning the healthcare staff to the places where the need is compelling and care needed the most (Mundy, Trowman and Kearney, 2018)Similar efforts have been taken by the Brazillian government where it constantly strengthens the policies and provides incentives to increase influx of primary care physicians, medical schools and other healthcare infrastructures in resources stricken area where the healthcare access is limited (Massuda, Atun and Castro, 2020)

Thailand also trains paramedical staff with a three year bachelor's degree to fill the human resource gap and deploying them at below district levels to provide care (Haines et al *et al.*, 2019).

Rwanda has sheer shortage of healthcare personnel (Table 5, 0.1 physician per 1000 population) with fundamentally zero advanced level physiotherapists, radiologists, anesthesiologists, midwives, or laboratory technicians and to fill their gaps, it coaches paramedicals and readies them for the same positions (Aly, Avila and Cram, 2000). Thailand also has rich pool of community health workers that maintains, one CHW per 20 households.

The family health strategy, which relies on CHW is the essence of UHC in Brazil. The extensive network CHW perform monthly visit to every family enrolled in the programme and run health promotion, prevention activities and check whether family members are complying with any treatment they are on (Massuda *et al.*, 2018). Thus, volunteers from community play a key role in managing the relationship between society and the healthcare system.

Conclusions

The comparisons of the health systems of different countries is useful as it offers potential learning of the different approaches the countries take to work out on the similar problems and challenges to achieve the common health system goals.

The study shows that systems not only go through turbulent reforms to adopt UHC but also go through continuous adjustments to meet changing demands and rising costs to sustain the UHC. The ripened systems like Japan is gradually shifting its healthcare model (bismarckian) to sustain the current challenge of presented by ageing population. This calls for an innovation in the way healthcare systems are financed. Thus UHC requires a continuous commitment. The health financing of the country should be such that it protects people from paying from their own pocket to avail healthcare that creates inequity in the level of healthcare utilization by different social class. The merger of different schemes has showed improvement in the cross-subsidization among the risk pools in the population as in the case of Thailand, Brazil and Turkey thus also improving equity and access to healthcare. In many of these countries, health sector reform and decentralization have brought about shifts in functions between the central and peripheral levels. The inequity can still revive even after UHC reforms and so regular monitoring and effective measure of the equity should be persistent with particular attention on the need of the population to ensure any detrimental or inimical effects are taken care with suitable policy introduction. The presence of strong political will, commitment and policy objectives to build a robust health financing, equitable service delivery and good governance is essential in order to successfully implement and keep going with such national level schemes. The Investments in guality primary health care will be the cornerstone for achieving UHC around the world. The evidence from the UHC success of developing and least developed nations confirms that UHC can be achieved even with modest but strategic funding to healthcare. The gatekeeping mechanism or referral system using well equipped and comprehensive PHC's have proved to not only reduce hospitalization but also the cost of the healthcare system as in the case of Thailand. The public health sector needs to assume the roles of promoter, provider, contractor, regulator, and steward. The private sector's role also needs to be clearly defined and regulated. The inherent shortage of healthcare professionals with poor geographical distribution is a global problem that can be handled with a strong network of ground level primary or community healthcare workers as in the

case of Thailand, Rwanda and Turkey. The informal healthcare workers thus can be trained to strengthen the referral system. Thus, a systemic reforms must ensure effective functioning and delivery of healthcare services in both rural and urban areas. Since UHC is not only about the provision of universal coverage but also the quality of the care, infrastructure and access to services provided under the coverage, it is imperative to develop robust public health financing structure, meet the skilled health workforce requirement to ensure improved health outcome.

Any developing country like India, that typically has large population and inadequate resources, struggles with meeting healthcare needs of its people. Such countries can learn from the example of these developed, developing and least-developed countries that have successfully and fairly achieved UHC by leveraging different policy levers, combination of cross- system elements and focus on health system components to gravitate to UHC realization that is inclusive and sustainable in the long-run. Thus justifying, that pursuing UHC though is expensive, complex and definitely not easy, but it is achievable.

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The State of Food Security and Nutrition : Building Climate Resilience for Food Security and Nutrition in the South West Region, Cameroon

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Abstract

Purpose: Climate change poses a growing threat to the achievement of adequate nutrition; it is projected to negatively affect human wellbeing and nutrition. The aim of this paper is to compare empirical literature from FAO food composition table (FCT) (1966) with our actual nutrients experimental data, to better understand the pathways linking climate change and nutrition after a period of 55 years (1966-2022) and to provide mitigating/resilience studies for this global syndemic between climate change and nutrition.

Design: A conceptual search on climate change related conditions that may affect agricultural/food/water chain and quality in South West region Cameroon was done. Secondly, staple foods were purchased to establish and compare their nutrient composition with the FCT. In a bid to mitigate and be resilient to the impact of climate on nutrients deficit, two pilot food studies (nutrients enhancement studies) were conducted in partnership with local small scale producers.

Findings: Results of conceptual framework revealed that, heat-waves, droughts, heavy precipitations and floods, due to climate and global environmental change events could be the key drivers behind the rise in malnutrition because they impact on water, crop yields, vegetation and food security. Furthermore, comparing 1966 food composition table with the analysed chosen staple foods showed a significant decrease of the micronutrient content with years; indicating that food systems are vulnerable to the increased variability in the weather and ecosystem as a result of climate change. Pilot studies with our partners revealed that formulated Fortified foods studied improved the micronutrients adequacy.

Keywords: Climate change, Nutrition, Food composition table, Human health, Nutrient, Staple foods, Food security

Introduction

Climate change and malnutrition in all its forms constitute two of the greatest threats to planetary and human health. The costs of unmitigated climate change, which will disproportionately affect low-income countries (Swinburn et al., 2019). The future of our health and that of our planet depend on our ability to massively reduce our contribution to climate change. No single solution will suffice. Nonetheless, changes in the food choice, and agricultural system can help mitigate climate change impacts on nutrition. The pandemics of malnutrition and climate change constitute a syndemic (Kahn et al., 2019): they interact in time and place, have synergistic adverse effects on each other, and importantly, share common underlying features.

As the climate changes, ensuring long-term access to sufficient and nutritious food for all becomes an even greater challenge faced by humanity. The effects of climate change on under-nutrition would be devastating, and would undermine current efforts to reduce hunger and ensure good nutrition. Despite the obvious critical situation and strong interconnection, food and nutrition security is still markedly absent in climate change negotiations. While strengthening further efforts on mitigation, it is time for climate negotiators, governments and donors to focus their attention on the consequences of climate change on under-nutrition/over-nutrition, and commit urgently to help the most vulnerable to adapt to an increasingly unpredictable climate and world. If not, irreversible consequences can be expected.

Adverse effects of climate change are a reality: the number of climate-related disasters (drought, floods, cyclones, etc.) in the previous decade has more than doubled relative to the nineties (WMO, 2021). It is proved that they are main drivers affecting food insecurity both in the aftermath of a disaster and in the long-term (Shimada, 2022). Climate-related events, disturbances in seasonal patterns, and gradual climate and temperature changes increase the overall risk of hunger. This is particularly alarming as there are still 842 million people suffering from hunger and more than 180 million children affected by under-nutrition (FAO, 2013). The situation is very likely to get worse considering the various predicted impacts of climate change. With a +2°C global average temperature increase, the most optimistic projected warming scenario is that the rate of undernourishment in the sub-Saharan African population will increase by 25% - 90% by 2050, relative to today (Lloyd et al., 2011; FAO, 2017). Climate change will affect the world's poorest households, whom have insignificantly contributed to greenhouse gas emissions. Furthermore, the most affected are those who have the least capacity to adapt to climate change related impacts.

The South West Region of Cameroon is blessed with a variety of natural resources such as; forests, water bodies (waterfalls, rivers, lakes, and ocean), mountains and abundant wildlife species. Moreover, climate in this region favors human habitation with temperature ranging from 16 to 26° C and an annual rainfall of 1432.2 mm, thus promoting agricultural practices. The most visible effect of urban expansion in South West Region of Cameroon is discernible in the urban and peri-urban areas, especially in Buea, Tiko and Limbe which have witnessed rapid population growth, ecosystem and environmental destruction and climate change (Nde-Fon and Assob, 2013).

Cameroon has witnessed a rapid and uncontrolled urban growth, especially at the peri-urban fringes (Akoko et al., 2019). With a constant rise and change of climate, urban dwellers are obliged to record a high household dependency ratio. In response, households have developed resilience techniques to cope with the changing climate and changing food. To survive within the urban and semi-urban areas of the region, the situation is more challenging among the poor whose purchasing power has consistently been eroded by falling real wages, inflation and the rising cost of living despite attempts by the government to increase minimum wages (Bronhilda, 2012). The

objective of this paper is to investigate on nutrition from a climate change perspective and to build resilience for food insecurity in the South West Region, Cameroon.

Materials and Methods

Study Design

This work is divided into three sections (Figure 1): First, a conceptual work linking environmental, anthropometrical and natural climate change key drivers in the South West Region that may impact nutrition. Secondly, comparison of empirical literature from food composition table (1953) published in 1966 by the FAO to explore the nutrients content of common staple foods with our actual experimental data (year 2022). Thirdly, in order to mitigate food insecurity, we proposed two pilot food studies conducted in partnership with local small scale producers as resilience strategy.

Study Area

This research takes into account three municipalities in the Fako Division of the South West Region of Cameroon, namely; Limbe, Buea and Tiko municipalities (Figure 2). Limbe is a seaside city located along latitude 4° 00' 60.00" N and longitude 9° 12' 60.00" E of the Greenwich meridian. The area called Limbe is actually comprised of the main city of Limbe, surrounded by smaller villages such as Batoke, Ngeme, Debunscha, Idenau, Mokundange, Bonadikombo, Wututu and Bonjongo. The population of Limbe is 72106. The majority of people here are traders, with those in the neighboring villages and creeks mostly surviving on fishing and agricultural activities (Geonames, 2022).

Buea is a small town located at the eastern slope of mount Cameroon, and lies along latitude 4° 09' 9.72" N and longitude 9° 14' 27.60" E of the Greenwich meridian. As of the 2013 census, it had a population of about 300,000 (NIS, 2015). It is made of localities like Molyko, Bunduma, Tole, Soppo, Bova, Mile 16, Mile 14, Gbitingi and Bokwaongo. Majority of the adult population are business people with a considerable student population since Buea is hosting one of the state Universities. Buea has a typical mountain equatorial climate with a rainy season and a dry season having an annual rainfall between 3000-5000 mm.



Figure 1: Overall Work Design Flow Chart



Figure 2: Map of the Study Areas

Tiko is a town located along parts of the Atlantic Ocean, along latitude 4° 04' 30.00" N and longitude 9° 21' 36.00" E, and is made of localities like Likomba, Tiko, Mutengene, Ombe, Mudeka, Mondoni, Misselele and Matte. It is host to the CDC and has a population of about 78,885 as at 2015 (NIS, 2015). The majority of people in this area are small scale farmers, and CDC workers.

Conceptual Framework on Natural and Anthropometric Activities Threatening Climate and Ecosystem of the Region

In order to conceptualize pathways and links that may alter nutrition at upland and wetland level of the study area (climate, environment, ecosystem and anthropometric activities on dry and wetland), we did a combination of scoping internet searches, snowballing, and citation tracking (Neba et al., 2021; Forkam et al., 2020; Akoko et al., 2019; Bate et al., 2019; Balgah et al., 2017; Azinwi et al., 2012; Molua, 2010; Molua, 2009; Feka and Manxano, 2008) to come up with frameworks. We merged nine frameworks which we found to accurately represent the climate and agricultural practices and nutrition science to create our own "meta-framework" (Figure 1). The choice of these frameworks was based on detailed comparison of identified frameworks and discussion among the article authors, which included representation of experts on climate change, public health nutrition, human activities, and natural seasonal change; the information derived was recapitulated into factors affecting highland and lowland of the studied area.

Nutritional Analysis

Empirical Food Composition Table

To compare empirical literature from food composition table (1953) published in 1966 by FAO, to explore the micronutrient content of common staple foods with our actual experimental data, to better understand the pathways linking climate change and nutrition after a period of 55 years (1966-2021) and to provide recommendations to mitigate the global syndemic between climate change and nutrition, a document (food Composition table) was downloaded from https://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_5/b_fdi_14-15/20430.pdf and https://www.fao.org/infoods /infoods/tables-and-databases/cameroon-archives/en/ with the following reference https://www.fao.org/infoods/infoods/infoods/tables-and-databases/cameroon-archives/en/.

https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers13-01/09986.pdf, and was used for comparison with our actual 2021-2022 food composition (empirical work).

Determination of our Actual Staple Food Composition

Sample Collection

The major foods which are cultivated in these municipalities include yellow corn maize, beans, cassava, cocoyams, plantains, yams, rice, Irish potatoes, tomatoes and sweet potatoes. The raw ingredients for the formulation of the complementary food and juices; were rice, corn, soybeans, sweet potatoes, irish potatoes, eggs, sugar, soybeans oil, pawpaw, watermelon, pineapple, oranges and sugar. They were bought from the local farmers of the region. The samples were taken in a polythene bag to the University of Buea Life Science Laboratory for formulation and nutritional analyses.

Proximate Analysis and Minerals Content

Standard procedures of AOAC were used to determine the moisture content, crude fat, crude protein (N x 6.25), crude fibers and ash. The total carbohydrate was obtained by difference. Energy value was calculated using the Atwater's conversion factors. Minerals were determined by Atomic Absorption Spectrophotometer, Hitachi Model 180-80, and Ion Chromatographic Analyzer ICA model IC 100 (AOAC, 2005).

Climate Resilience/Mitigating Pilot Studies with Partners: Methods of Nutrient Enhancement: Dietary Diversification, Formulation, Fermentation Fortification

In order to solve any possible micronutrient deficiencies that may have been impacted by climate and ecosystem modification on the nutrient quality of foods, two pilot food studies were conducted in partnership with local small scale producers (Hest, Jourlaitcam, Saphi Beverages Scoop and Islamic Development Bank). The studies focused on formulation of natural juice by blending several ingredients while the other focused on formulation and fortification of complementary food using germination/fermentation technology. This was done on staple foods in a bid to improve on the human micronutrients requirement.

First Pilot Study: Juice Formulation

Sample Collection

Healthy mature, ripe lemon, honey and orange fruits and fresh ginger were bought from local farmers at the Buea Central Market. The samples were taken to the University of Buea Life Science Laboratory in a polythene bag for juice formulation and nutritional analyses.

Sample Preparation

The fruits (orange and lemon) were washed, weighed, peeled and reweighed. The lemon and orange juices were extracted separately using an electronic juice extractor (Citrus juicer, CJ625). Both juices were filtered and then bottled and kept for formulation and pasteurisation.

The ginger on the other hand, was washed, weighed, chopped into smaller sizes and blended with 600mL of water using a Moulinex (PHILIPS). The ginger due to its rich fibre content had much chaff hence, was squeezed and filtered with a 0.2µm sieve, before the tea sieve was used. This was also ready for formulation and pasteurisation.

Juice Formulation

Five (5) juice formulas (Blending recipes termed: F1, F2, F3, F4 and F5) (Table 1) were made ranging from 5% to 10% orange or lemon fruit base and were labelled from F1 to F5. This was done using a formulation table (Table 1). The juices were pasteurized at 90 °C for 10 minutes. They were allowed to cool for 45 minutes and filled into sterile labelled bottles and were analysed nutritionally as described previously in section 2.4.2.

Juice	Orange	Lemon	Ginger	Honey	Table	Vanilla	Water	Total
Code					sugar	sugar		(mL)
F1	5	0	5	10	5	0	75	100
F2	10	0	5	10	0	5	70	100
F3	0	10	5	10	5	0	70	100
F4	0	5	5	10	5	0	75	100
F5	0	10	5	10	0	5	70	100

Table 1: Formulation Table

F1, F2, F3, F4 and F5= different formulated juices

Second Pilot Study: Complementary Food Formulation

Sample Preparation and Processing

Preparation of Flours

Malted corn flour was prepared by soaking overnight, kept in a cool dry place, and covered with plastic bags for germination. The fermented and malted corn flour was obtained using the optimal processing conditions as defined by Kameni et al. (2008)

Rice flour: This was done using the method described by An-I (2004).

Sweet potato flour: This was produced using the method proposed by Maninder and Kawaljit (2016).

Irish potato flour: This was produced using the method described by Maninder and Kawaljit (2016).

Soy protein flour: It was prepared following processing unit described by Wang et al. (2004).

Egg white flour: 90 fresh eggs were cracked open, and the yolks removed. The whites were dried at 50°C for 24 hours, ground using a dry electric blender, and sieved. The resulting flour was stored in zip-lock bags, inside an air-tight container at room temperature (Nahariah et al., 2018)

Extraction of Fruit Juices for Micronutrient Fortification of Foods

Fifteen medium sized oranges, 2 large pineapples, 2 large pawpaw fruits and one large watermelon were washed in running tap water and peeled. The peeled fruits were juiced individually using an electric juicer machine, sieved using a 0.1mm sieve, and stored in separate sterile containers at 4°C till when it was ready to be used as natural fortificants to enrich the formulae.

Blending, Formulation and Fortification

Table 2 is a summary of how the flours and juices were mixed in ten different proportions to give ten different food blends. Blend A, for example, consisted of 58g of malted corn flour, 10g of egg-white flour, 10g of soybeans flour, 8g of sugar, 5ml of soybeans oil, 50ml of watermelon juice, 10ml of orange juice, 40ml of pawpaw juice, 5ml of milk flavour, 5ml of coconut flavour and 12g of baking powder. After mixing of flours, juices and flavours, the mixtures were homogenized using an electric blender, placed on sterile trays and dried at 50°C for 24 hours using a hot-air oven. The resulting dry matter were ground using a dry blender, sieved and the fine flours (instant baby ready to eat foods) stored in sterile zip-lock bags at room temperature.

Food samples/	Α	В	С	D	Е	F	G	Н	I	J
Blends										
Corn Flour (g)	58	0	0	0	29	29	29	0	0	0
Rice Flour (g)	0	58	0	0	29	0	0	29	29	0
SP Flour (g)	0	0	58	0	0	29	0	29	0	29
IP Flour (g)	0	0	0	58	0	0	29	0	29	29
Egg White Flour (g)	10	7	8	6	10	8	6	5	3	5
Soy Protein Flour (g)	10	7	8	6	10	8	6	5	3	5
Sugar (g)	8	10	0	7	10	5	7	5	7	5
Soybeans oil (ml)	5	5	5	5	5	5	5	5	5	5
Watermelon juice (ml)	50	50	50	50	50	50	50	50	50	50
Pineapple juice (ml)	0	10	0	10	0	0	0	10	0	0
Orange juice (ml)	10	0	10	0	10	0	0	0	0	0
Pawpaw juice (ml)	40	40	40	40	40	50	50	40	50	50
Milk flavour (ml)	5	5	5	5	5	5	5	5	5	5
Coconut flavour (ml)	5	5	5	5	5	5	5	5	5	5
Baking soda (g)	12	12	12	12	12	12	12	12	12	12

Table 2. Formulation of Ten Different Complementary Food Blends

SP: Sweet potato; IP : Irish potato

Statistical Analysis

Raw data were computed using Microsoft EXCEL 2007. All data were presented as mean \pm SD and was analysed using one-way analyses of variance (ANOVA) using Graphpad software to test the level of significance at 5 % probability (p<0.05). Bonferroni Test was used to separate/compare the means where significant differences existed.

Results and Discussion

Conceptual Framework: Natural and Anthropometric Activities Threatening Climate/Ecosystem of the Region

The first section of the conceptual framework (Table 3) lays that heat waves, season short term trends, variation in precipitation or temperature, and meteorological events such as heat waves, droughts, and floods (Erudef, 2021) due to climate and global environmental change events are the key drivers behind the rise in hunger because they impact on water, food and nutrition security, particularly in developing countries. These were observed through many years of weather/meteorological variability. Consequently they alter relationships among crops, pests, weeds, pathogens; and exacerbate several trends including increasing water scarcity, decline in fishery /sea food and ocean productivity as well as an induced decrease crop productivity, land degradation, high market prices, and negative impacts on livelihoods, and increased malnutrition (Erudef, 2021). Climate change will impact malnutrition by affecting patterns in weather, including trends in precipitation and temperature, as well as the frequency and magnitude of extreme weather events. It is difficult to study climate associations (Molua, 2009). Erudef (2021) reported that, over the past 2 decades, this region has been exposed to climate change as a result of Greenhouse Gas (GHG) emission.

South	Climatic and ecosystem Impact	References
West		
Location		
Upland (Buea Highland)	 Wild and bush fire (destruction of vegetation); Huge smoke : air pollution (particles, sulfur dioxide, ozone, Carbon monoxide) Disappearance of bush meats and edible insects causing pressure on cow meat price. Destruction of sol, erosion, destruction or activation of soil microorganisms (azobacter). Soil leaching, leading to excessive utilization of fertilizer, insecticides and chemicals that facilitate plant growth and affect original food taste. Change of agricultural practices to adapt to new soil. Deforestation. Urbanization: destruction of cultivable surface Violent winds, high temperatures, irregular rainfall, floods and landslides which endanger communities' ecosystems and the services they provide. Poor agricultural techniques, poor waste disposal, plastic pollution Increase in epidemics food and water scarcity changes in 	Neba et al., 2021; Akoko et al., 2019; Forkam et al.,2020; Feka and Manxano, 2008; Molua, 2009; Molua, 2010; Azinwi et al., 2012; Bate et al., 2019; Balgah et al., 2017

Table 3. Summary of the Conceptual Framework Showing Climate Change Conditions that Pose a Growing Threat to Nutrition in the Study Area

	temperature and precipitation, leading to droughts and floods.	Nde-Fon and
	- Seasonal inconstancy (modification of rain flow rate and rain	Assob, 2013
	precipitations.	Aaron et al., 2014
Wetland	- Flow of mangrove, destruction of mangrove for firewood that	Neba et al, 2021
(Tiko,	affect phytoplankton's, development of toxic wild algae that	Erudef, 2021
Limbe)	reduce dissolvable oxygen, fish scarcity, animal migration.	
	- Increase of sea level, Water acidification, heavy metal	
	accumulation	
	- Change of vector, pest and insects life cycle,	
	- Water borne disease, Contamination of ground water by run-	
	off water and toilet.	
	- Human anthropometric activities: laundry contaminate	
	drinking and domestic water sources (well, river, bore water,	
	food contamination, food intoxication,	

Consequently, the population are facing abnormal recurrence of extreme weather phenomena such as violent winds, high temperatures, irregular rainfall, floods and landslides which endanger communities' ecosystems and the services they provide. These environmental hazards are as a result of uncontrolled human activities which are not in conformity to environmental principles and disciplines, hence causing global warming. These activities include, but not limited to deforestation, poor agricultural techniques, poor waste disposal, plastic pollution and the absence of infrastructural town planning. There is much scientific evidence that climate change is responsible for increase in epidemics, food and water scarcity, changes in temperature and precipitation, leading to droughts and floods, poor agricultural yields and malnutrition (Nde-Fon and Assob, 2013). As climate change appears to be progressing too quickly for decisions to be delayed, we need to develop national and local climate change institutional frameworks to strengthen the coordination, networking and information flow at different levels of governments and local civil society to have better response to climate change eradication.

Comparison of Food Composition Table (1953) and Actual Data of Staple Food (2021-2022)

Table 4 presents the composition of some selected staple foods grown in the South West Region of Cameroon. According to this, different types of food are found in the region including cereals, tubers/roots, vegetables and fruits. The different micronutrients vary according to the type of food concerned with the highest amount of carbohydrates and proteins found in cereals in general and, particularly in fresh corn and the smallest value in fruits. The highest value of ash (total minerals) was found in fruits. The highest amount of calcium was found in pineaple, whereas phosphorous and iron were found in corn and rice in highest amount. This table also presents the nutrient composition of some staple foods recently evaluated for their nutrient content. This study revealed that the amount of micronutrients initially present generally reduced, while macronutrient increased and the food became more starchy and bulky. These modifications of staple food nutrients can lead to malnutrition (micronutrient deficiency and over-nutrition). Diet is changing too, especially among urban groups, with increased consumption of ultra-processed food and beverages, beef and dairy products, whose production is associated with high GHG emission

intensities (Gill et al., 2015). These changes between 1966 and 2022 may be due to the rising levels of carbon dioxide from human activities. Gill et al (2015) reported that CO_2 can make staple crops less nutritious; elevated CO_2 generates hidden hunger by reducing mineral contents in cereal crops.

Research led by Myers et al. (2014) found that when food crops like wheat, corn, rice and soy are exposed to CO_2 at levels predicted for 2050, the plants lose as much as 10 % of their zinc, 5 % of their iron, and 8 % of their protein content. Studies by Nelson et al. (2009) revealed that the number of malnourished will probably increase due to climate change, with the majority of these children living in sub-Sahara Africa. People eat different diets and therefore the starting points in making dietary changes to move towards healthy and sustainable diets vary between people (Reynolds et al., 2019).

	Proteins(g)		Carboh	Carbohydrate		Minerals		Calcium		Phosphoru		Iron (mg)	
			(g)		(Asn	i (g))	(mg	1)	s (mg)			
Food	FC	AC	PC	AC	PC	AC	Р	AC	PC	AC	PC	AC	
							С						
Fresh corn	9.8	9.0	76.4	77.4	1.1	0.8.	12	10	220	218	2.0	1.7	
Dry corn	6.6	6.6	48.8	50.4	0.5	0.4	32	30	137	133	3.2	2.2	
Banana	1.2	1.0	25.5	28.5	0.8	0.3	4	3	40	39	0.7	0.6	
Plantain	1.1	1.0	27.6	26.9	0.8	0.4	11	12	3.5	1.4	0.5	0.3	
Cassava	0.9	1	37.7	38.5	1	1.	25	20	30	29	1.2	1.0	
Tomato	1.2	0.9	5.6	3.2	0.4	0.1	10	7	45	42	0.7	0.6	
Cocoyam	2.8	1.8	33.4	38.4	1.2	1.0	8	7	35	30	0.9	1	
Rice	7	4.7	79.1	53.1	0.6	0.6	5	5	90	80	1	0.6	
Yam	3.2	5.2	22.1	20.5	0.8	0.7	24	21	27	26	0.2	0.1	
Sweet potato	1.8	3.3	25.3	30.6	0.9	0.8	36	30	60	56	1.4	1.2	
Irsih potato	2.1	2.1	21.4	27.8	1.4	1.4	12	9	40	35	0.9	0.9	
Mango	0.6	0.4	14.3	17.0	0.3	0.2	20	15	15	17	0.6	0.6	
Pineapple	0.6	0.5	15.1	18.2	0.3	0.4	56	51	15	16	0.9	0.8	
Avocado	2	2.1	6	8.3	1	0.9	18	14	57	51	0.8	0.6	
Orange	0.8	0.6	12.2	9.2	0.5	0.3	28	22	28	18	0.1	0.2	

Table 4.	Nutrient	Composition	of	Some	Staple	Foods	Derived	for	FAO	(1966)	Food
Composit	ion Table										

FC: food composition from food composition table FAO, 1966 ; PC : Actual composition 2021-2022

There has been relatively limited consideration, however, of potential climate impacts on malnutrition through mechanisms of changing nutrient content of foods (Figure 3). Macronutrients and micronutrients are part of a healthy diet, and they ensure appropriate development and wellbeing and prevent diseases. Children aged between 6 months and 5 years in particular may suffer from micronutrient deficiencies (WHO, 2014). Vitamin A, calcium, and iron are the most common deficiencies and a concern for public health (WHO, 2021). Iron deficiencies in pregnant

women increase the risk of maternal and child mortality, and low birth weight. Calcium deficiency affects the bone development of children, while vitamin A deficiency raises the probability of blindness and mortality due to infectious diseases during childhood (WHO, 2014). A 2018 study by Scheelbeek et al (2018) systematically investigated the effect of environmental change on vegetable and legume yields, in particular exploring projections in the potential future nutritional quality of vegetable and legume yields under environmental change. Generally, climate change affects the molecular function, the developmental process, the morphology and the physiological responses of plants (Myers et al., 2014). Elevated CO₂ promotes higher yields, but alters the equilibrium of the plant carbon metabolism and mineral composition (Soares et al., 2019: Nakandalange and Seneweera, 2018). For example, drought and high temperatures induce oxidative damage in legume plants according to the review of Soares et al. (2019), and this is more likely to have an effect on the macronutrients.

Some modelling and experimental studies conducted in laboratory have identified correlations between climate change or meteorological variation and a decrease in food quality in terms of diversity, nutrient density, and safety (Patz et al., 2005). Carbon dioxide (CO₂), for example, may have a negative effect on the nutritional content of several crops (Figure 3) (FAO, 2016; Porter et al., 2014). For example, concentrations of iron and zinc in wheat and rice are more likely to be reduced due to increased greenhouse gas emissions (Myers et al., 2014). Higher CO₂ associated with climate change is hypothesised to lead to micronutrient deficiencies (Smith et al., 2017; Müller et al., 2014; Myers et al., 2014). Among people worldwide that lack food, more have deficiencies in essential nutrients; 76% of the world's population gets most of its daily nutrients from plants-yet climate change is already causing droughts and flooding that can destroy staple food crops. If extra CO₂ in the atmosphere makes those crops less nutritious (Figure 3), it will be even harder to feed the world's growing population. While severe food insecurity and hunger are associated with lower obesity prevalence, mild to moderate food insecurity is paradoxically associated with higher obesity prevalence among vulnerable populations (Swinburn et al., 2019).



Figure 3: Climate change and nutrients (FAO, 2016 and NZFSSRC, 2019)

Mitigating Pilot Studies with Partners for the Nutrients Enhancement: Dietary Diversification, Formulation and Fortification

Proximate and Mineral Composition of Formulated Juices

Proximate Composition of Juice

The proximate composition of the best formulated juice is shown on Table 5. The protein content of the fruit juices was low. The general low protein content of fruit juice has also been reported for orange/pineapple juice blends and fresh beetroot juice (Ohwesiri et al., 2016; Emelike et al., 2015). According to Emelike et al. (2015) fruit juices are not good sources of protein. The carbohydrate content is higher than a reported range of 8.16 - 16.19% for orange/pineapple juice blends (Ohwesiri et al., 2016) and 7.3% for fresh beetroot juice (Emelike et al., 2015). The variations in these values could be associated with different fruits being analysed. The ash (mineral) content (0.51-1.13%) of the juices was similar to the range of 0.42% - 2.68% for orange/pineapple juice blends (Ohwesiri et al., 2015). Generally, the juices were rich in carbohydrate and moisture, but low in protein, fibre, fat and ash. The difference between the treatment means was significant (P ≤ 0.05).

Code	Moisture	Protein	Carbohydrate	Fiber	Fat (g/100mL)	Ash (g/100mL)
	content (%)	(g/100mL)	(g/100mL)	(g/100mL)		
F1	$96.84_{a} \pm 0.00$	$0.56_{b} \pm 0.00$	$21.83_{a} \pm 0.48$	$0.01_{a} \pm 0.00$	$0.11_{a} \pm 0.01$	$0.63_{a} \pm 0.00$
F2	$97.10_{a} \pm 0.36$	$0.01_{a} \pm 0.00$	$20.30_{a} \pm 0.99$	$0.02_{a} \pm 0.01$	$0.10_{a} \pm 0.00$	$0.51_{a} \pm 0.00$
F3	$96.84_{a} \pm 0.00$	$0.02_{a} \pm 0.00$	$22.99_{a} \pm 1.34$	$0.09_a \pm 0.00$	$0.10_{a} \pm 0.01$	$0.51_{a} \pm 0.01$
F4	82.45 _b ±1.86	$0.01_{a} \pm 0.00$	$20.15_{a} \pm 2.04$	$0.02_{a} \pm 0.00$	$0.05_{b} \pm 0.01$	$1.13_{b} \pm 0.01$
F5	$79.31_{b} \pm 2.58$	$0.06_a\pm0.00$	$16.39_{b} \pm 1.99$	$0.07_{a} \pm 0.00$	$0.10_{a} \pm 0.01$	$1.02_{b} \pm 0.00$

Table 5: Proximate Composition of Juice

Results are expressed as mean ± standard deviation; a,b, Means with the same letter in the same column are not significantly different at p>0.05. F1, F2, F3, F4 and F5= different formulated juices

Mineral Analysis of Juice

Mineral content of the best formulated juice is presented on Table 6. The most abundant mineral was Potassium followed by Calcium while Zinc was the least. F1 was most abundant in Phosphorus and Magnesium, F2 in Iron, Zinc and Sodium, F3 in Potassium and F5 in Calcium; F4 was generally low in minerals. Minerals were significantly different ($P \le 0.05$). This is in agreement with the results reported by Dosumu et al. (2009) and Ijah et al. (2015). The micro minerals, Iron (Fe) and Zinc (Zn) were present in trace amounts. Potassium is an essential mineral that works to maintain the body's water and acid balance. As an important electrolyte, it plays a role in transmitting nerve impulses to muscles, in muscle contraction and in the maintenance of normal blood pressure. While deficiency of potassium is rare, there is some concern that a high sodium-to-potassium intake ratio may be a risk factor for high blood pressure (Whitney and Rolfes, 1999). Generally, inadequate intake of micronutrients (minerals) has been associated with severe malnutrition, increased disease conditions and mental impairment (Dosumu et al., 2009).

Mineral	F1	F2	F3	F4	F5
(mg/mL)					
Р	$0.12_{c} \pm 0.02$	$0.08_{b} \pm 0.04$	$0.10_{b} \pm 0.01$	$0.01_{a} \pm 0.00$	$0.06_{b} \pm 0.00$
Fe	$0.06_{b} \pm 0.01$	$0.10_{b} \pm 0.03$	$0.07_{b} \pm 0.01$	$0.06_{b} \pm 0.02$	$0.06_{b} \pm 0.01$
Ca	$0.21_{c} \pm 0.05$	$0.19_{c} \pm 0.00$	$0.20_{c} \pm 0.03$	$0.19_{c} \pm 0.00$	$0.24_{c} \pm 0.00$
Mg	$0.07_{b} \pm 0.01$	$0.06_{b} \pm 0.03$	$0.06_{b} \pm 0.02$	$0.05_{b} \pm 0.00$	$0.04_{a} \pm 0.01$
Zn	$0.01_{a} \pm 0.00$	$0.02_{a} \pm 0.01$	$0.01_{a} \pm 0.00$	$0.01_{a} \pm 0.00$	$0.01_{a} \pm 0.00$
Κ	$0.23_{c} \pm 0.08$	$0.23_{c} \pm 0.08$	$0.29_{c} \pm 0.00$	$0.23_{c} \pm 0.08$	$0.23_{c} \pm 0.08$
Na	$0.08_{b} \pm 0.03$	$0.10_{b} \pm 0.00$	$0.08_{b} \pm 0.03$	$0.06_{b} \pm 0.00$	$0.06_{b} \pm 0.00$

Table 6: Mineral Composition of Juice

Results are expressed as mean ± standard deviation; a,b,c, Means with the same letter in the same row are not significantly different at p>0.05. F1, F2, F3, F4 and F5= different formulated juices

This juice formulation section showed that blending or diversifying fruit can be a good mitigating strategy for the global challenges of ensuring sufficient safe and nutritious food for all. As our planet's population continues to grow, and as the impacts of climate change and environmental pollution become more visible to all, juice fortification and formulation solutions need to be promoted because it will be a good strategy to satisfy a daily human nutrient requirement in terms of recommended daily allowance (RDA).

Complementary Food Formulation

The nutritional composition of the formulated food is presented in table 7. For the ash contents, three out of five (Formula B, C and D) formulas had higher ash contents than the recommended value of 2.9. Formulas A and E had the least ash contents (2.65%), and these were the only two formulas whose ash contents were within the reference range. The formula with the highest ash content turned out to be B, with 3.70% (Table 7). In terms of RDA for total mineral, formulae A and E were the best. The presence of ash in the formulas is indicative of the presence of minerals in them, and hence the formulated complementary foods could be used in the fight against micronutrient deficiency in children. WHO recommends an ash content of 2.9g for every 100g of food sample for complementary foods, and the five formulas all have ash contents within this range, with some slightly higher, like formula B (the most preferred formula), whose ash content was up to 3.7%. Mahmoud and Mohammed (2014) found an ash content of 2.91% for their complementary food formulated from rice, sweet potatoes, faba beans and peanut oil, while Tiencheu et al. (2016) and Akinola et al. (2014) recorded higher ash contents (4.32% - 4.85% and 5.21%-7.52%, respectively) for their own formulations made out of egg whites, fermented maize, pawpaw and beans, guinea corn, millet, groundnuts, carrots and crayfish.

The fiber content of all the formulas was higher than the recommended value of 3.8% for complementary foods. However, there was no significant difference (P>0.05) between the fibre content of any of the formulas and the standard recommended value (3.8%) by WHO. The findings in this study were contrary to findings reported by Shewangzaw et al. (2021) from their complementary food formulas made from a mix of soybeans, teff, white maize and honey bee larvae, where they found much lower fibre contents in the range of 2.75% - 4.52%.

For protein contents, all samples had very high protein than the standard value of 15%, which is prescribed by WHO for complementary foods. This difference between the formulas and the standard value was however insignificant (P>0.05) for four out of five formulas. The lowest protein content was found in formula C (17.72%) and E (18.11%). The high protein content of the five formulas could be considered a good thing, since protein energy malnutrition rates are still so high in Africa. Mahmoud and Mohammed (2014) found a 7.48% and 4.94% protein content for rice and sweet potato flours respectively, implying that rice has more crude proteins than sweet potatoes. The germination and malting of the maize used in this study improved on its protein content, making the blend with maize as main starch source to have the second highest protein content, after the one with rice.

The results obtained from the analysis of the fat content of the formulas showed them having fat contents in the range 9.5% - 14%, all of which are above the reference value of 8%. The only formula which showed a statistically significant difference (P<0.05) between its fat content and the standard value was formula D. The lowest fat content was recorded in E (9.5%), though this was still higher than the reference (Table 7). A higher fat content could be a good, as well as it could increase the energy density of food; but must decrease it shelf live. Aduni et al. (2016) found fat contents in the range of 3.15% to 14.35% for their nine instant weaning foods made out of crayfish, carrot, irish potatoes, soybeans and Ndop rice.

The carbohydrate contents were all lower than the standard value of 64.68%, with the least content obtained from B (38.74%), and the highest from C (63.58%) (Table 7). Anigo et al. (2010) obtained dissimilar results for carbohydrate content from their formula (88.75% - 90.89%) which was a blend of soybeans, groundnuts, guinea corn, sorghum, corn and millet in different proportions.

	Ash	Fibre	Protein	Fat	Carbohydrate.	Energy
Samples	Content	Content	Content	Content	Content	Content
	(%)	(%)	(%)	(%)	(%)	(Kcal)
WHO						
standard	2.9	3.8	15	8	64.68	400
Formula A	2.65±0.15 ^a	7.13±1.43 ^a	25.82±3.07 ^a	11.00±1.00 ^a	53.14±2.92ª	414.8±8.40 ^a
Formula B	3.70±0.40 ^a	7.32±1.42 ^a	37.72±9.54 ^b	11.50±0.50 ^a	38.74±8.49 ^b	409.3±0.30 ^a
Formula C	3.10±0.00 ^a	7.29±0.73 ^a	17.72±0.66 ^a	11.00±2.00 ^a	63.58±2.04ª	433.2±1.80 ^b
Formula D	2.95±0.05 ^a	6.43±2.23 ^a	20.13±0.44 ^a	14.00±0.00 ^b	56.53±0.29ª	432.6±0.60 ^b
Formula E	2.65±0.05 ^a	9.27 ± 0.15^{a}	18.11±1.05 ^a	9.50 ± 0.50^{a}	59.24±1.50 ^a	394.9±2.70 ^a

Table 7: Proximate Analysis of the Formulae

The superscripts a = statistical significance at p < 0.05 and b = significance at p < 0.01 compare to WHO reference pattern value

The energy content of the five formulas, which is a function of the carbohydrate, fat and protein content of each one of them, was higher than the recommended value of 400Kcal for four out of the five formulas., it was noted that apart from formula E whose energy content was below (394.9Kcal) the reference value of 400Kcal, all other formulas had energy contents above this standard value (Table 7). Comparing these values with the standard value showed no statistically significant difference (P>0.05) between formulas A, B, E and the standard, while formulas C and D showed statistically significant differences from the standard (P<0.05). Araro et al. (2020) got similar results in their complementary food mixes made with sweet potatoes, brown teff, and dark red kidney beans. Their mixes had energy levels in the range of 339.07% - 356.74%, values which were all slightly lower than the recommended value. The high energy levels of the five formulas, which are as a result of high protein, carbohydrate and fat levels, makes them a suitable complementary food to overcome the deficit that may have been caused by climate change and environmental challenges.

Micronutrient Analysis

Table 8 gives a summary of minerals analyses of the five formulae, pap and the WHO standard values for each of these micronutrients. From the mineral analysis of the samples, the calcium content of the formulas was above the reference value (341.2mg/100g). This difference was however, not statistically significant (P>0.05), except for formula B. Among the five formulas, formula B, whose main starch source was rice, had the highest calcium content (632mg/100g), followed by C with 454mg/100g of calcium, then formulas D and E with calcium contents of 408.0mg/100g. It is of utmost importance that the novel formulas are up to standard with their calcium content, as calcium is extremely important for the brain and bone development of the infant. Plahar (2018) found similar results for his sweet potato-based formulas which contained (357.89mg/100g-256.57mg/100g)), groundnuts but lower calcium content (100.73-91.96mg/100g) in similar sweet potato-based formulas which did not contain groundnuts. Ajiwe and Nwaigbo (2014) had dissimilar results in their formulas made from different proportions of yellow maize, millet, red sorghum, wheat, brown spotted African yam bean, bambara groundnut, pigeon pea and soybeans (42.19 - 140.76mg/100g).

The iron content of the formulas ranged from 4.73mg/100g (formula E) to 8.59mg/100g (Formula C). They were generally lower than the reference value of 8.5mg/100g, except C, with sweet potatoes as main starch source, which had an iron content of 8.59mg/100g. This could be explained by the fermentation process done on the corn, since fermentation has been shown to enhance the bioavailability of several micronutrients which are usually coupled to phytates in the unfermented grains. Satter et al. (2014) found similar results from their complementary food formulated from wheat, soybeans, sugar, mango, skimmed milk and jackfruit. They had values for iron content in the range of 7.56 - 8.22mg/100g. Ikujenlola and Adurotoye (2014) had much higher values of iron content (260-390mg/100g) in their complementary food formulated from high protein maize and steamed cowpea. The infant's daily requirements for iron are met, as the role of iron in the body is very vital in malaria endemic zone like Cameroon, and it is important that its RDA is always met.

The WHO standard for phosphorous, in a complementary food, is set at approximately 100mg/100g. All five formulas were found to be higher in phosphorous than the standard value; with C having the highest phosphorous content (136.49mg/100g), followed by A with a content of 119.28mg/100g. The range of phosphorous values were from 109.04-136.49mg/100g, with formula C, containing sweet potato as main starch source, having the highest phosphorous content. Except for formula C, the difference in phosphorous content between the standard values and the values obtained in the formulas was not statistically significant (P>0.05). Tiencheu et al. (2016) had much higher values (286.37-365.08mg/100g) for phosphorous in their complementary food formulated from maize, pawpaw, red beans and mackerel fish meal, same as Anigo et al. (2010) who had higher values in the range of 148.98 – 219.98mg/100g in their formulations made from guinea corn, sorghum, maize, millet, soybeans and groundnuts.

The analysis of zinc content revealed that all five samples were lower than the recommended value of 3.7 mg/100g set by the WHO. The range of zinc content of the five samples was 1.47 mg/100g to 2.35 mg/100g. This difference between the standard value and the values obtained from the samples was statistically significant (P<0.05) for two out of five samples (C and D), but not statistically significant for the other three formulas (A, B and E). Among the five formulas, formula A was richest in zinc (2.35 mg/100 g), followed by B with 2.32 mg/100 g. Gemede et al. (2020), had slightly higher values, in the range of 2.73 - 3.00 mg/100 g for zinc content of their complementary food formulated from maize, pea and anchote flours, while Asouzu and Nkemjika (2020) had similar results ranging from 1.52-2.61 mg/100 g in their complementary food formulated crayfish and carrot flour.

The analysis of magnesium content of the five samples showed that the two formulas with the highest magnesium contents were C (85.19mg/100g) and H (75.75mg/100g). Formula B had a magnesium content of 72.91mg/100g, while A had 70.6mg/100g. The least formula was D, with 58.32mg of magnesium per 100g of formula. The WHO standard for magnesium in complementary foods is 48.7mg/100g, and this standard was clearly met and surpassed by all five samples, though the difference was statistically insignificant (P>0.05) for all five samples. Bolarinwa et al. (2019) had dissimilar values, ranging from 0.21- 0.24mg/100g while Mohammed et al. (2021) had similar results of magnesium content, a value of 54.44mg/100g for their complementary food mix made up of an improved variety of yellow maize, soybeans and African catfish meal.

The sodium content of the five formulas was analyzed and it was realized that there was a statistically significant difference (P<0.01) between four of the formulas (B, C, D and E) and the reference value of 60mg/100g. Only formula A had no statistically significant difference with the reference value. For the five formulas, the sodium content ranged from 102.42mg/100g (formula A) to 189.41mg/100g for formula B. Also, the analysis of potassium content revealed that formulas B, D and E had similar potassium contents (611.49mg/100g), and this was the highest value observed among the five formulas; C had a potassium content of 728.82mg/100g, while A had least value (319.2mg/100g). The recommended value for potassium for a complementary food is 408.7mg/100g. Apart from formula A whose value for potassium content was below standard, all the other formulas had higher than the standard values for potassium content. Aduni et al. (2016), on the other hand, had similar results for sodium and potassium contents for their complementary foods, with sodium ranging from 74.50 – 88.17, and potassium from 241.87 – 1322.27mg/100g. The most preferred formula (B) had the highest sodium content and satisfactory potassium content as well. Solomon (2005) obtained values of 11.1-21.1mg/100g for sodium content, and 99.7 to 129.7mg/100g of potassium for a complementary food based on rice, maize, acha grains, soybeans, groundnuts, bambara nuts and cravfish, both of which were below the standard.

This section showed that infant's micronutrients requirements in terms of recommended dietary allowance (RDA) that cannot be covered due to climate change consequences on food composition, and can be improved through dietary diversification, fermentation, germination and food formulation strategies applied in this study. Such mitigation techniques need to be encouraged and promoted.

SAMPLES	WHO standard	Formula A	Formula B	Formula C	Formula D	Formula E
Ca (mg/100g)	341.2	378.0±14.0 ^a	632.0±12.0 ^b	454.0±2.0 ^a	408.0±16.0 ^a	408.0±16.0 ^a
Fe (mg/100g)	8.5	6.03±0.21 ^a	6.27±1.3 ^a	8.59±2.7 ^a	6.30±0.8 ^a	4.73±0.3 ^a
P (mg/100g)	100	119.28±8.8 ^a	109.98±2.3 ^a	136.49±8.4 ^b	114.63±1.4 ^a	109.04±10.7ª
Zn (mg/100g)	3.7	2.35±0.63 ^a	2.32±0.37 ^a	1.56±0.06 ^b	1.47±0.18 ^b	1.87±0.28 ^a
Mg(mg/100g)	48.7	70.6±21.74 ^a	72.91±9.73 ^a	85.19±12.01 ^a	58.32±9.72 ^a	75.75±6.31 ^a
Na (mg/100g)	60	102.42±0.0 ^a	189.41±14.2°	162.02±13.18 ^b	136.72±12.13 ^b	136.72±12.13 ^b
K (mg/100g)	408.7	319.2±0.0 ^b	611.49±22.5°	728.82±0.0 ^c	611.49±22.5°	611.49±22.5°

Table 8: Micronutrient Analysis of the Formulated Complementary Foods

The superscripts a = statistical significance at p < 0.05, b = significance at p < 0.01 and c = significance at P < 0.001, compared to WHO reference pattern value.

Conclusion

The impacts of climate change are perceptible in the South West region and are likely to be greater in areas with existing poor food security, as the nutrient content from 1966 to 2022 were noted here after a period of 55 years. Therefore, government and organisations need to put more financial and technical support toward adaptation in least developed countries, as currently, financial contributions remain insufficient to meet adaptation needs. Nutrient enhancement strategies should be vulgarised and promoted through training of trainees. We therefore recommend that nutritional education campaigns should be organised at community levels to empower the key actors, with practices (diversification and fortification) before 2030; Additionally, Green Climate Eco-nutritional fund should be created to encourage efforts of developing countries in responding to the challenge of climate change. Immediate additional public funding is required in order to support these adaptive strategies of the world's poorest to climate change. Better nutritional health can improve the resilience of a population to climate-related shocks and stresses. Governments and donors should support nutrition focused adaptation and Disaster Risk Management strategies and target women and children most at risk for under-nutrition as a priority. Guaranteeing food and nutritional security should be a priority for donors that finance adaptation measures. Therefore, these findings may contribute to effort geared toward Cameroon's attaining the SDG's, notably SDG 3 on health and wellbeing, SDG 13 on climate change and SDG 2, zero hunger.

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Trends of Malaria in the South West Region of Cameroon: Overview, Challenges and Perspectives (SDG3)

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Abstract

Background: The South West Region of Cameroon falls in the large equatorial forest of the south, where malaria parasite transmission is high and perennial. It is one of the two English- Speaking Regions affected by the on-going social crisis with displaced populations which could constitute an enormous challenge to malaria control efforts. If we hope to attain Target 3.3 of the Sustainable Development Goals, then it matters that evidence-based data as the basis for aggressive measures to reduce the burden of malaria in the region be generated. A review of the literature of malaria in the region was done to establish a trend in epidemiological, parasitological and entomological indicators of malaria and identify gaps in knowledge and make proposals for future steps.

Methods: A total of 47 scientific and policy documents were extracted from online bibliographic databases and reviewed. The major findings were noted, the gaps identified and future steps proposed.

Major findings: *Plasmodium falciparum* is the dominant species responsible for malaria infection in the region. Infection in children, pregnant women and adults range from 7.1% to 43.3%, 20.3% to 43% and 5.38% to 25.6%, respectively. The main vector that transmits malaria is the *Anopheles gambiae s.l.* Artemisinin and its derivatives are the drugs for malaria treatment.

Conclusion: All the studies conducted on malaria over the years were sporadic in nature and no trends of malaria transmission in the region could be established.

Perspectives: There is need for longitudinal prospective studies to monitor trends in malaria in the region.

Keywords: South West Region, Malaria, Trends, Epidemiology, Social crisis, Sustainable Development Goal.

Introduction

Malaria is a mosquito-borne disease of humans and other animals caused by parasitic protozoans of the genus *Plasmodium*. It is transmitted through the bite of an infected female *Anopheles* mosquito. The World Health Organization (WHO) reported 229 million malaria cases in 2019 of which an estimated 215 million occurred in the African Region accounting for about 94% of cases.

The majority of malaria cases (82%) and deaths (94%) that were averted occurred in the African Region. Cameroon accounts for 3% of this number (215 million) (World Malaria Report, 2020).

Despite decades of control and prevention efforts, malaria remains one of the greatest causes of morbidity and mortality in Cameroon. According to the National Malaria Control Programme (NMCP) 2008 annual report, malaria accounts for 35% to 43% of all deaths in health units, 50% to 56% of morbidity among children under the age of 5, 40% to 45% of medical consultations and 30% to 47% of hospitalizations. It is also the cause of 26% of absences in the workplace and 40% of the health expenditure of households. Malaria is responsible for 49% consultations and 59% of hospitalizations during pregnancy leading to abortions and premature labour and deliveries as well as low birth weight, all exposing the babies to early deaths and mothers to death during delivery (NMCP Report, 2008; Ngum *et al.*, 2010). In 2019, 25,876,387 Cameroonians were at risk of malaria infection, 4,266,684 confirmed cases, 11,233 deaths, 66,071 under five deaths (WHO World Malaria Report, 2020; UNICEF, 2020).

Although malaria is endemic nationwide, the level of endemicity greatly varies from one geographical, ecological and climatic zone to another. The three main epidemiological zones linked to geo-climatic variations are the sudano-sahelian zone (areas of the Far North and North regions), the large savanna area of interior plateau (Adamawa region) and the large equatorial forest of the south (the remaining 7 regions of the southern part of the country). The existing climatic conditions are favorable for the development of the malaria vectors and the parasites. *Plasmodium falciparum* is the most common species of *Plasmodium* (95%), followed by *P. malariae* and *P. ovale* (NMCP Report, 2012; Ngum *et al.*, 2010).

The South West Region, which is one of the ten administrative regions of Cameroon, falls in the large equatorial forest of the south, where malaria parasite transmission is high and perennial. The climatic conditions and ecological settings of this region are optimal for continuous transmission throughout the year. The region comprises six administrative Divisions and 31 Sub Divisions. It has a population of 1,553,300 inhabitants covering a surface area of 25,410 km². The region has an east-west extension of about 110 km and north-south, it is approximately 190 km. It is located between latitude 3. 80° - 6.70°N and longitude 8.30° - 10.20° E with altitude ranging from 0 to 4095 m.a.s.l. The region is bordered by the North West Region in the north, the Atlantic Ocean in the south, the Littoral and West Regions in the east and Nigeria in the west. The region is characterized by a succession of vegetation including mangrove at the Atlantic coast through the deep equatorial evergreen forest to the humid savannah in the far north (Akwaya Sub Division) of the region. The climate comprises two seasons, the rainy season from March to October, while the dry season goes from November to February with annual rainfall varying between 1500 mm/ year inland to 4000 mm/year on the sea coast (Suchel, 1998). The region is considered as belonging to a holoendemic stratum with high and perennial malaria parasite transmission but in the highlands, it is seasonal with high transmission observed during the rainy season months (Wanji et al., 2012).

Antonio-Nkondjio and colleagues (2019) reviewed the malaria situation in Cameroon in 2019, including that of the South West Region. However, covering the whole country, some important trends and details for the region might have been left out.

The social crisis affecting the South West region of the country with a displaced population could be affecting malaria epidemiology in the area and this could constitute an enormous challenge that could impede malaria elimination or control efforts in this region. If we hope to attain Target 3.3 of the Sustainable Development Goals (SDGs) by ending epidemics of malaria and ensure healthy lives and promote the well-being of all at all ages by 2030, then it matters that evidence-based data as the basis for aggressive measures to drastically reduce the burden of malaria in the region be generated. This paper attempts a review of the literature of malaria in the South West Region in order to establish a trend in epidemiological, parasitological and entomological indicators of malaria and identify gaps in knowledge and make proposals for perspective and future steps.

Methodology

Data Retrieval

Information on malaria in Cameroon and the South West Region in particular were extracted from online bibliographic databases. PubMed, Google and Google Scholar were used to search for information. Terms used to guide these searches included malaria parasites and transmission, malaria vectors and ecology, malaria incidence and prevalence, morbidity and mortality rates, epidemiology, pathologies, diagnosis, treatment and management, vector control, *Plasmodium*, LLINs, insecticide resistance, Anopheles. Information was also extracted from published reports: WHO, UNICEF, NMCP, Cameroon Demographic Health Surveys (DHS). The search period included 1960 to 2021. The search resulted in 100 articles. Fifty three papers were excluded because they were not reporting data from the South West Region of Cameroon. Scientific publications downloaded were categorized as follows: *Plasmodium* species (4), Epidemiology (11), Genetics (1), Immunology (3), Pathology (7), Diagnosis (4), Treatment and management (4), Vector biology (4), Prevention and control (9).

Results

Situation of Malaria in the South West Region

Plasmodium Species

Very few studies have attempted identification of the *Plasmodium* species circulating in the South West Region. Wanji *et al.* (2008) evaluating the performance and usefulness of the Hexagon Combi rapid diagnostic test in asymptomatic children in the Mount Cameroon region revealed the dominance of *Plasmodium falciparum*. The limitation of the Hexagon rapid test was its inability to detect mixed infections. Kwenti and colleagues in 2017 identifying *Plasmodium* species in five epidemiological strata in Cameroon including the coastal areas of Limbe, by polymerase chain

reaction (PCR), concluded that *P. falciparum* was the only species causing clinical malaria in the target population. Kimbi and colleagues in 2005, reported *P. vivax*-like asymptomatic infections in 33.3% of school children (Kimbi *et al.*, 2005). However, diagnosis was done by light microscopy and the researchers were not certain about the speciation, especially because of the notion that Africans are refractory to *P. vivax* infection due to lack of the Duffy antigen receptor needed by *P. vivax* to attach and invade red blood cells. As such, there was no follow-up study for proper identification by the researchers.

One of the few studies that employed molecular typing revealed a substantial *Plasmodium vivax* infection of 14.7% (13/87) in asymptomatic adults in a rural community in Buea (Fru-Cho *et al.*, 2014). The study also revealed a prevalence of 50% (6/12) Duffy positive individuals. The results of this study provided the first molecular evidence of indigenous *P. vivax* infection in the South West Region and Cameroon at large. Larger studies are needed in order to establish the prevalence of *P. vivax* infection in the region.

Malaria Vectors

Although there are 48 *Anopheles* species recorded throughout Cameroon, only 18 are responsible for malaria transmission (Fontenille *et al.*, 2004; Antonio-Nkondjio *et al.*, 2006; Ayala *et al.*, 2009; Sinka et al., 2010). The principal vectors of malaria in Cameroon are *Anopheles gambiae* (s.s.), *An. funestus* (s.s.), *An. arabiensis*, and *An. coluzzii. An. carnevalei*, *An. coustani*, *An. hancocki*, *An. leesoni*, *An. marshallii*, *An. melas*, *An. moucheti*, *An. nili*, *An. paludis*, *An. pharoensis*, *An. ovengensis*, *An. rivulorum-like*, *An. wellcomei* and *An. ziemanni* play a secondary role (Carnevale *et al.*, 1992; Njan *et al.*, 1993; Fontenille *et al.*, 2000; Antonio-Nkondjio *et al.*, 2002).

In the South West Region of Cameroon, a few studies have identified the malaria vectors implicated in the transmission of malaria. Wanji *et al.* (2003) investigated the biting habits, feeding behaviour and entomological inoculation rates of different *Anopheles* species during the dry and rainy season in the Mount Cameroon region. Five *Anopheles* species were identified: *Anopheles gambiae s.l., An. funestus, An. hancocki, An. moucheti* and *An. nili. An. gambiae, An. funestus* and *An. hancocki,* recorded during both seasons, were the main vectors of malaria in the region. *An. gambiae s.s.* was the only member of the *An. gambiae* (Giles) complex. These three species had their peak activity between 1 and 2 am. The sporozoite rate, for all vectors together, was significantly higher in the rainy season (9.4%) than in the dry season (4.2%) with all the species infected by *Plasmodium falciparum*. The average inoculation rate was 0.44 infective bites per man per night, which adds up to 161 infective bites per year in this study area. No malaria vector was caught at 1200 m a.s.l.

Bigoga *et al.* (2007) studied malaria vectors and transmission dynamics in coastal south western Cameroon and reported *Anopheles gambiae* (78.2%), *Anopheles funestus* (17.4%), *Anopheles nili* (7.4%) as the dominant species. *Anopheles gambiae* accounted for 72.7% of transmission, *Anopheles funestus* (23%) and *Anopheles nili* (4.3%). The entomological inoculation rate of 287, 160 and 149 infective bites/person/year was recorded for Tiko, Limbe and Idinau, respectively. Amvongo-Adjia *et al.* (2018) investigated the bionomics and vectorial role of anophelines in wetlands along the volcanic chain of Cameroon with Tiko, Meanja, Kumba and Mamfe (all in the South West Region) as part of the study sites. Eight malaria vectors: *Anopheles arabiensis, An. coluzzii, An. funestus* (s.s.), *An. gambiae, An. hancocki, An. melas, An. nili* and *An. ziemanni,* were found biting humans. Anophelines were more exophagic (73.6%) than endophagic (26.4%), showing a marked nocturnal activity (22:00–4:00 h) for *An. coluzzii* and *An. gambiae* while *An. funestus* (s.s.) was mostly caught between 1:00 and 6:00 h and *An. ziemanni* having an early evening biting behaviour (18:00-00:00 h). The transmission level was low with entomological inoculation rates estimated to 0.7 infected bites per person per month (ib/p/mth) in Tiko and 1.4 ib/p/mth in Mamfe.

Boussougou-Sambe *et al.* (2018) assessed the susceptibility of *Anopheles gambiae* (*s.l.*) mosquitoes from South-West Cameroon to deltamethrin, permethrin and malathion identified two species of the *An. gambiae* (*s.l.*) complex, *An. coluzzii* and *An. gambiae* (*s.s.*) in all three study locations with high proportions of *An. coluzzii* in Limbe (84.06%) and Tiko (92.2%), while in Buea, *An. coluzzii* (55.6%) and *An. gambiae* (*s.s.*) (44.4%) occurred almost in the same proportions.

Epidemiology

In changing climatic and environmental conditions coupled with different malaria prevention and control measures put in place by the government, the epidemiology of malaria in the region cannot be expected to remain the same over the years. Temperature, precipitation, vegetation and altitude are important predictors of the geographical distribution of malaria in Cameroon (Massoda et al., 2015). During the last two decades, an increase in temperature of 0.4 °C and decrease in rainfall of 10% – 20% have been reported, compared to the period 1951–1980 (Sighomnou, 2004). Most of the studies that have been conducted on malaria in the region have focused on the incidence and prevalence in vulnerable populations (children and pregnant women). Ikome et al., (2002), reported a prevalence of 50.9% uncomplicated malaria and 7.1% cerebral malaria in children below 15 years of age in Limbe. Between 2008 and 2019, varied prevalence of malaria parasitaemia were reported in children below 15 years in the Mount Cameroon area ranging from 24.8% to 43.3% (Wanji et al., 2008; Nyasa et al., 2015; Kimbi et al., 2013; Sumbele et al., 2015; Bate et al., 2016; Eposi et al., 2019). The highest prevalence (43.3%) was recorded in 2019, after many years of free subsidized treatment for children and free Long-Lasting Insecticide-Treated bed nets (LLINs). Outside the Mount Cameroon area. Fokam et al. (2016) and Nyasa et al. (2021) reported prevalence in children of 40.7% and 21.35% in the Tombel and Nguti areas of the Kupe Muanengouba Division respectively. Asoba et al. (2009) and Fokam et al. (2016) reported prevalence of 43.2% and 20.3% in pregnant women in the Mount Cameroon area (Buea, Muea and Mutengene) and Tombel Health District respectively. Studies in adult populations recorded prevalence of 25.6%, 32.3%, 26.5% and 5.38% in the Mount Cameroon area (Ebako et al., 2010; Fru-Cho et al., 2014; Nyasa et al., 2015; Nyasa et al., 2021) and Kupe Muanengouba Division. The least prevalence (5.38%) was in Kupe Muanengouba.

Diagnosis

Early diagnosis and treatment of malaria remains critical to preventing death, reducing the disease and its transmission (WHO, 2015; World malaria report, 2020). Current malaria management guidelines recommend prompt parasitological confirmation of all suspected malaria patients by microscopy and/or rapid diagnostic test (RDT) prior to antimalarial treatment (WHO, 2015). Some communities in malaria-endemic areas lack healthcare facilities, and diagnosis of malaria relies predominantly on its clinical presentation which is nonspecific. Although presumptive diagnosis of malaria is less expensive (Ansah et al., 2013), the accompanying prescription could lead to the treatment of patients without malaria (Perkins et al., 2008), over prescription of antimalarial drugs (Rafael et al., 2006), thus contributing to antimalarial drug resistance (White, 2004). It is worth noting that WHO recommends parasite-based diagnosis first for older children, adults and all suspected cases of malaria regardless of patient age (Bell et al., 2018). The examination of Giemsa-stained blood smears for the detection of malaria parasites using light microscopy therefore remains the gold standard for malaria diagnosis, as it provides information on both parasite species and density (Moody, 2002). However, microscopy requires basic laboratory infrastructure, guality equipment and reagents and is labour intensive and needs a trained technician. In order to overcome the deficiencies of light microscopy, RDTs have thus been designed as alternatives. RDTs require little training, produce rapid as well as prompt results after 15 to 30 minutes, require no laboratory infrastructure and therefore allow them to be used in the most remote settings. RDTs are vastly sensitive and specific compared with microscopy and also compare favourably with the polymerase chain reaction (PCR) (Moyeh et al., 2019; Berry et al., 2008). However, RDTs are limited mainly by their inability to detect infections at low parasitaemia. In addition, false positive or negative results may be reported due to the persistence of target antigen even after successful treatment or deletions in the PfHRP2 gene, respectively (Haditsch, 2004; Gamboa et al., 2010). Nevertheless, they are affordable, easy-to-perform, fast, reliable and effective diagnostic point-of-care tools for malaria case management especially in endemic rural settings and areas with limited laboratory facilities (WHO, 2011).

It is worth noting that newer diagnostic techniques such as amplification of parasite DNA with polymerase chain reaction are specific and can detect low concentrations of parasites but take time and requires specialised equipment and are thus not suitable in most field settings. The use of malaria RDT has expanded both in endemic and non-endemic settings, with over 60 different RDT brands and more than 200 developed products (Bell, 2011). Yet, results from field trials suggested highly variable field performance. Procuring excellent quality RDTs does not necessarily guarantee good field performance because factors such as shipping, handling and storage could affect the RDT accuracy (Bell, 2011).

Despite persistent high malaria prevalence, and the continuous influx of RDTs into our markets, the surveillance of RDTs in Cameroon and the South West Region in particular seems virtually ignored. Between 2008 and 2021, a number of studies evaluated the validity and usefulness of different brands of RDTs in the South West Region. Wanji *et al.* (2008) evaluated the performance of the Hexagon Combi[™] Rapid Diagnostic Test in children with asymptomatic malaria in the Mount Cameroon area and obtained 85.33%, 95.05% and 91.40% for sensitivity, specificity and

accuracy respectively. They also noted that sensitivity and specificity increased with increase parasitaemia. It was concluded that the Hexagon Combi[™] Rapid Diagnostic Test can be used in mass surveillance programmes. Teh et al. (2019) investigated the concurrence of CareStart™ Malaria HRP2 RDT with microscopy in a population screening for Plasmodium falciparum infection in the same area. Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV) and accuracy were 82.4%, 76.6%, 57.4%, 91.9% and 78.2%, respectively. Sensitivity depended on parasitaemia and reached 96.1% at densities ≥200 parasites/µL of blood. The overall concurrence of CareStart[™] Malaria HRP2 pf Ag RDT with microscopy in the detection of *P. falciparum* infection was moderate and most useful at parasitaemia \geq 200 parasites/µL of blood. The conclusion drawn from this study was that the RDT could be effective as a diagnostic test for confirmation of clinical cases of malaria, but its applications in population screening with a higher proportion of asymptomatic cases are limited. Moyeh et al. (2019) compared the accuracy of four malaria diagnostic methods in a high transmission setting in coastal Cameroon and observed that SD Bioline can be an addition to or alternative to light microscopy in the diagnosis of malaria in the South West Region of Cameroon. With a diagnostic sensitivity that is above 90% as required for confident diagnosis of malaria, SD Bioline could replace light microscopy in remote areas with difficult access to reagents and electricity. Apinjoh et al. (2021) evaluated and compared the diagnostic performance of a PfHRP2/pLDH-based malaria rapid diagnostic test (mRDT) on patients' blood, saliva and urine relative to conventional light microscopy and nested PCR at outpatient clinics in the Buea and Tiko Health Districts of southwestern Cameroon. The sensitivity and specificity of presumptive diagnosis, light microscopy and mRDT on blood, saliva and urine were 86.9% and 19.7%, 77.8% and 96.1%, 75.8% and 96.6%, 74.5% and 93.1%, and 70.7% and 81.8%, respectively. They concluded that the agreement between mRDT on saliva (k = 0.696) and microscopy (k = 0.766) compared to PCR was good.

HRP2 is the most widely used antigen in mRDTs either alone or in combination with other antigens, due to its abundance, specificity for *P. falciparum* infection, and high sensitivity and thermal stability (WHO, 2012). However, large numbers of genetic deletions of *pfhrp2* and/or *pfhrp3* genes in natural populations of *P. falciparum* have been reported in parasite populations in Peru and subsequently in many countries including Africa (Gamboa *et al*, 2010; Maltha *et al.*, 2012; Koita *et al.*, 2012; Berhane *et al.*, 2018).

In Africa, where malaria is endemic and the use of RDTs is widespread, there is scarce information on *pfhrp2/3* deletions, although a few surveillance studies have reported on their existence. Systematic reviews by Agaba *et al.*, in 2019 (Figure 1), and Kojom and Singh in 2020 provided unequivocal evidence of the existence and occurrence of *pfhrp2* and *pfhrp3* gene deletion.



Figure 1: Distribution of *pfhrp2/3* gene deletion across Africa (Agaba *et al.*, 2019)

So far, there are no data available for *pfhrp2* and *pfhrp3* gene deletion in Cameroon. Determining the existence and prevalence of deletion is crucial for accurate malaria diagnosis which may help in curbing the disease. Esum *et al.* (*in press*) recently concluded an investigation on this phenomenon in febrile patients in Buea and Limbe Health Districts of the South West Region and may provide the first evidence of *pfhrp/pfhrp3* gene deletions in the region and Cameroon.

Prevention and Control

The main strategies for malaria prevention in Cameroon are intermittent preventive treatment (IPT) for pregnant women and vector control through the use of LLINS, especially for pregnant women and under-five children (Ntonifor & Veyufambom, 2016). The WHO in 2004 recommended
a package of intermittent preventive treatment in pregnancy (IPTp) with sulfadoxinepyrimethamine (SP) and use of insecticide-treated nets (ITNs), together with effective case management of clinical malaria and anaemia. During the period 2010–2017, 1.45 billion artemisinin-based combination therapy (ACT) treatment courses were delivered by NMPs, of which 1.42 billion (98%) were in the WHO African Region.

In Cameroon, this policy was adopted and implemented by the Ministry of Public Health in 2004 immediately after WHO recommendations and consisted of at least three free SP doses between the 16th and the 36th weeks of pregnancy alongside the use of ITNs. These interventions are commonly delivered in antenatal clinics (ANC) through the collaboration between malaria and reproductive health programmes (World Malaria Report, 2015). According to the World Malaria Report in 2011, in most malaria endemic countries in Africa, 40 % of pregnant women sleep under ITNs. In Cameroon, data on coverage on malaria control interventions show that only 13.1 % of children belowr five years sleep under insecticide-treated mosquito nets, 37% of pregnant women receive the second dose of Sulfadoxine-Pyrimethamine and only 58% of complicated cases of malaria are promptly and properly managed. In a recent study in Obala Health District (Cameroon Coalition Against Malaria: Obala Malaria Campaign Baseline Survey, Feb 2010), the coverage was as follows: 15.1% for ACTs, 41% for LLINs, 67% for IPT2.

Treatment and Case Management

WHO recommends artemisinin-based combination therapies (ACTs) for the treatment of uncomplicated malaria caused by *P. falciparum* (WHO, 2015). By combining two active ingredients with different mechanisms of action, ACTs are the most effective antimalarial medicines available today. WHO currently recommends five ACTs for use against *P. falciparum* malaria. The choice of ACT should be based on the results of therapeutic efficacy studies against local strains of the parasite.

The Cameroon government launched the policy of free malaria treatment which was adopted in Cameroon in 2011 and 2014, for the treatment of simple and severe malaria respectively (MINSANTE,PNLP, 2014; Sieleunou *et al.*, 2015). The free malaria treatment is a package that includes subsidized diagnosis of malaria and treatment for under five children and pregnant women for severe and simple malaria provided in all health facilities (Khun *et al.*, 2008; O'Meara *et al.*, 2010; MINSANTE, PNLP, 2014; Sieleunou *et al.*, 2015).

After the introduction of the malaria prevention and control policy in Cameroon, few studies in the South West region have evaluated the effectiveness of the measures adopted. Fokam *et al.* (2016) assessed the usage and effectiveness of intermittent preventive treatment and insecticide-treated nets on the indicators of malaria among pregnant women attending antenatal care in the Buea Health District. They reported coverage of ITN as 32.4 % while that of ITPp was 63.2 %. Malaria prevalence was least (7.2 %) amongst women using both IPTp- SP and ITN, while those with no intervention had the highest malaria prevalence of 18.6 %, and concluded that repeated doses of SP in combination with ITN use are effective in reducing malaria parasitaemia and improving haemoglobin level of pregnant women. Kimbi *et al.* (2012) assessed the efficacy and

tolerability of Malartin and Sulphadoxine-Pyrimethamine combination against uncomplicated falciparum malaria in Dibanda, south west Cameroon. They administered malartin for 3 days and SP as a single dose on day 0 and observed an overall success rate of 92.53% of the drug combination. The prevalence of anaemia decreased from 22.99% at enrolment to 9.77% on day 14. The study concluded that malartin and SP are effective and safe against uncomplicated falciparum malaria and suggested that this drug combination is a better alternative for the patients that react to malartin/amodiaquine combination in Cameroon.

Anchang-Kimbi *et al.* (2020) evaluated the coverage and effectiveness of intermittent preventive treatment in pregnancy with sulfadoxine–pyrimethamine (IPTp-SP) on adverse pregnancy outcomes in the Mount Cameroon area, South West Cameroon. The prevalence of falciparum malaria was 18.5% where uptake of SP was \geq 3 doses and three or more dosing was associated with increased falciparum malaria density notably among women from semi-urban areas. The prevalence of low birth weight infants was 7.3% and was generally observed in anaemic and semi-rural women. They concluded that, reported uptake of IPTp with \geq 3 SP doses in the Mount Cameroon area did not provide observable prophylactic benefits and suggested that SP resistance efficacy studies are necessary.

The Demographic Health Survey of 2018 (DHS Report, 2018) reported that the household population of the South West Region with access to ITN was 46%.

Drug Resistance

Since early 60s the sensitivity of the plasmodium parasites to chloroguine, the best and most widely used drug for treating malaria, has been on the decline. Newer antimalarials were discovered in an effort to tackle this problem, but all these drugs are either expensive or have undesirable side effects. Moreover after a variable length of time, the parasites, especially the falciparum species, have started showing resistance to these drugs also. The Asia Pacific region has traditionally been the focus of resistance to antimalarial drugs and now we have artemisinin primarily the Thai-Cambodian resistance on border. (WHO :Drua Resistance.http://www.who.int/tdr/research/progress9900/methods/malaria-resistance.htm: Accessed December10, 2021) If it is not contained, it can have global implications and the most serious effect would be in Africa which has a high disease burden and the highest mortality rates. The best way to prolong the use of the drug would be to use it in combination with other antimalarial drugs (Whegang et al., 2010).

In Cameroon, resistance to anti-malarial drugs has been reported (David et al., 2009). Chloroquine, which was most accessible and used as the first line treatment for uncomplicated malaria, developed resistance, which was depicted for the first time in 1985 in the Limbe Township of the South West Region and later in other localities in the country with high rates of therapeutic failures observed. Confronted with this situation, other molecules (Amodiaquine, Sulfadoxine - pyrimethamine as well as more recent artemisinine associated therapies) were proposed for use in chloroquine resistant areas (Whegang *et al.*, 2010). However, therapeutic failures to Artemisinine Combination Therapies (ACT) are now being registered in some towns in Cameroon

including Limbe, where a therapeutic failure rate of 14% related to combination of Atesunuate and amodiaquine + sulfadoxine-pyrimethamine was reported between 2004 and 2006 (NMCP Strategic Plan, 2007 - 2010).

Moyeh *et al.* (2018) investigated the effects of Drug Policy Changes on evolution of molecular markers of *Plasmodium falciparum* resistance to chloroquine, amodiaquine, and sulphadoxine-pyrimethamine in the South West Region of Cameroon. They reported that the Pfcrt 76T mutation was observed in 91.7% (211/230) of samples while the mutant 86Y, 184F, and 1246Y of the Pfmdr1 gene were observed in 58.8% (133/226), 82.1% (183/223),and1.3% (3/226), respectively. The study showed that the evolution of treatment policies in Cameroon had led to the gradual return of the sensitive genotype of the 4-aminoquinoline resistance markers. The gradual return to the CQ-sensitive genotype showed that return to its clinical efficacy can be anticipated as was the case in Malawi.

Insecticide Resistance

The prevention of malaria in Cameroon is based essentially on vector control through use of Insecticide Treated Mosquito Nets (ITN) and Indoor Residual Spray (IRS) (David *et al.*, 2009). The efficacy of IRS and ITNs depends, among other things, on the proportion of vectors resting on the sprayed surface and the susceptibility of the vectors to the insecticide used. It is therefore important to monitor development and extent of insecticide resistance in the particular vector population. A number of insecticide sensitivity studies have been carried out by the NMCP as well by other research institutions in different parts of the country. The results derived through these studies show that there is optimum sensitivity of *An. gambiae s. l.* to carbamates and organophosphates. However, *An. gambiae* is more resistant to DDT than is *An. arabiensis* in the tropical zone. No vector resistance, what so ever, has been noticed in Maga and Tiko for all insecticides tested. (NMCP Strategic Plan, 2007 – 2010)

Boussougou-Sambe *et al.* (2018) investigated the insecticide susceptibility status of *Anopheles gambiae* (*s.l.*) in South-West Cameroon four years after long-lasting insecticidal net mass distribution. Two species of the *An. gambiae* (*s.l.*) complex, *An. coluzzii* and *An. gambiae* (*s.s.*) were identified in all three study locations with high proportions of *An. coluzzii* in Limbe (84.06%) and Tiko (92.2%), while in Buea, *An. coluzzii* (55.6%) and *An. gambiae* (*s.s.*) (44.4%) occurred almost in the same proportions. Tested samples were found resistant to pyrethroids (deltamethrin and permethrin) in all locations (< 90% mortality), with > 3-fold increase of KDT50 values compared with the Kisumu susceptible reference strain of *An. gambiae* (*s.s.*). However, the mosquito populations from Limbe and Buea were fully susceptible to malathion. The L1014F kdr was found in both *An. coluzzii* and *An. gambiae* (*s.s.*) with the highest frequencies found in *An. gambiae* (*s.l.*) populations from Tiko (94%) and Buea (90%) compared with the Limbe population (66%). No kdr L1014S was observed in analyzed samples. Their findings indicate ongoing development of *An. gambiae* (*s.l.*) resistance to pyrethroids used in impregnating LLINs and suggest the use of malathion as an alternative insecticide for IRS in complementarity with LLINs.

Conclusion

All the studies conducted on malaria in the region over the years were sporadic in nature and no trends of malaria transmission in the region could be established. About 95% of the research on malaria in the region was conducted in the Mount Cameroon area (Fako Division) and very little is known in the other areas. It is therefore difficult to determine whether malaria control efforts will produce the desired results in the region by 2030.

Challenges

Insecurity due to the ongoing social crisis affecting the South West Region of the country may present an uncondusive environment for research and handicap accessibility to remote health districts, health areas and communities.

Environmental Sanitation is a very weak component of malaria vector control efforts in the South West Region. This warrants a change in the mentality of the population through tailored sensitization messages adapted to the socio-cultural context of the region.

Perspectives

There is need to use molecular biology techniques to identify *Plasmodium* and *Anopheles species* circulating in the region in order to adopt appropriate control strategies. A multi-disciplinary approach to design and conduct longitudinal prospective studies to monitor trends in malaria epidemiology, parasitology and entomology in the region in the next eight years is paramount. These are long-term studies carried out regularly, e.g. monthly or half-yearly, for the purpose of evaluating the impact of control measures. They provide up to date information on incidence, prevalence, morbidity and mortality rates as well as changes in vector density, infection rates, behaviour, and susceptibility of vectors to insecticides.

Quality assurance procedures and structures are needed to monitor the performance and guarantee the quality of the RDTs used in the region.

Collaborative studies are envisaged between the University of Buea and the National Malaria Control Programme and Municipal councils. Funds for these studies will be solicited from national and international bodies through competitive research grants.

Acknowledgements

We are grateful to the University of Buea SDG, Review and Technical Committees for their coordination and scientific inputs. We thank the Vice Chancellor of the University of Buea for supervising this paper.

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Understanding the True Healthcare Impact of Nonprofits Serving the Navajo Tribe During the COVID-19 Pandemic

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Abstract

Undeniably, the disruption caused by the COVID-19 pandemic has elevated healthcare needs and regressed advancement made toward Sustainable Development Goal 3. Marginalized and low-resource populations, such as the Navajo tribe, were disproportionately affected by the pandemic, as was seen in metrics such as morbidity rates, food security, and domestic abuse/ intimate partner violence occurrences. As a result, the pandemic exposed heightened pain points of vulnerable populations and introduced opportunities for nonprofits to address the urgent healthcare needs of susceptible communities. This paper determines the sustainable impact of the medical supply campaigns hosted by 501c(3), Project Embrace, as a case study to further evaluate the success of nonprofits and the progress of Sustainable Development Goals during the pandemic.

Keywords: Indigenous, Healthcare, Nonprofit, Pandemic, Rural, Supply Chain

Introduction

Nonprofit organizations play an essential role in the progression of the Sustainable Development Goals (SDGs). Often, nonprofit organizations work closely with marginalized and disenfranchised communities to provide essential services to advance the agendas of the SDGs. The COVID-19 pandemic heightened the demand to achieve these goals, as the pandemic has either halted or reversed the progress of the SDGs (Zhenmin, 2021). Indeed, this was the case in indigenous communities within the United States. Health disparities were intensified during the pandemic as the demand for healthcare services increased, while funding and resources for indigenous tribes were diminished, and access to healthcare was devastated (Shah et al., 2020). As a result, the emergence and prevalence of community initiatives developed and deployed by nonprofits, such as Project Embrace, increased throughout the duration of the pandemic. These community initiatives allowed for the progression of Sustainable Development Goal 3, despite the obstacles that the pandemic has presented. Project Embrace is focused on addressing SDG Target 3.8 within the Navajo community as the provision of essential, and affordable healthcare services is necessary to counteract the damage incurred by the pandemic (United Nations, 2021). However, despite the increase in community initiatives, the impact and implications of these programs have seldom been discussed. It is necessary to evaluate these initiatives and their overall effectiveness

in progressing the SDGs, specifically during the pandemic. Thus, the purpose of this paper is to evaluate the effectiveness of the medical campaigns facilitated by Project Embrace to the Navajo Reservation, in the context of SDG Target 3.8.

Background

The Navajo Community Prior to the Pandemic

The United States has had a poor relationship with indigenous communities, including but not limited to the Navajo tribe (Tajmajer, 2021). As a result, these communities face a lack of access to basic and necessary infrastructure, including but not limited to clean piped water, electricity, internet, road development and maintenance, housing, healthcare, and education (The World Bank, 2021). Consequently, this has and continues to contribute to a lower quality of life and poor health outcomes for indigenous communities. Although there are a variety of social determinants of health, the scope of this evaluation is limited to factors within the healthcare system, and more specifically the provision of necessary medical technologies for lifestyle assistance.

One of the most effective public health policies to improve health outcomes is the implementation of handwashing to reduce the spread of disease. Having access to clean piped water to wash hands is necessary to slow the spread of disease within a household and the greater community (Purvis Lively, 2021; Larson, 2020). The Navajo community has long suffered from a lack of access to clean piped water and it is estimated that 9,500 homes on the Navajo Reservation do not have piped water (Brown, 2020). Consequently, many homes must transport in clean water which can be financially burdensome, time consuming, and may reduce handwashing frequency.

Similarly, barriers in navigating healthcare infrastructure greatly contribute to poor health outcomes (McMaughan, Oloruntoba and Smith, 2020). In particular, socio-economic status and distance traveled for care can affect the ability to access healthcare. The Federal Reserve Bank of Minneapolis (2017) found that the Navajo Reservation had a poverty rate of 40.5% compared to a reported U.S. poverty rate of 14.6% (Federal Reserve Bank of Minneapolis, 2017). Furthermore, socio-economic status can contribute to transportation difficulties that may inhibit a patient's ability to access the healthcare system (Rural Health Information Hub, 2011). In context, the Navajo reservation is roughly the size of West Virginia, and Indian Health Services runs just 14 hospitals throughout the Navajo Nation. It was determined that on the Arizona portion of the Navajo Reservation, the average distance traveled to the nearest provider was 26.81 miles and the distance to the next provider was 44.57 miles (Navajo Nation Primary Care Area: 2020 Statistical Profile, 2021). This data does not account for the distance traveled to see a specialist or to a Level I trauma center, greatly affecting the Navajo community's ability to seek specialized and comprehensive emergency care.

Furthermore, many of the people who live on the reservation are in a food desert, with only 13 full-service grocery stores throughout the greater reservation. The average resident has to drive hours to buy food, and extreme poverty prevents many from buying more expensive items such as fresh produce. As a population, American Indians and Alaska Natives have the highest rates

of diabetes, resulting in high demand for mobility and lifestyle assist technology (NICOA, 2019). In the Navajo Area, 1 in 5 have diabetes and it is estimated that 75,000 have prediabetes, according to (Noble, 2017). Cycles of poverty further enable the increase of noncommunicable diseases throughout the greater tribe.

Project Embrace facilitated medical campaigns in four of the six counties that include the Navajo Reservation (San Juan County, UT; Navajo County, AZ; Apache County, AZ; and McKinley County, NM). In 2019, County Health Rankings compiled social determinants of health data to rank each U.S. county's health outcomes and health factors against all other counties in the respective state. All four aforementioned counties scored in the bottom 25% for their state in both health outcomes and health factors (County Health Rankings, 2020a; County Health Rankings, 2020b; County Health Rankings, 2020c; County Health Rankings, 2020d). This data illustrates the grim reality of health outcomes within the Navajo community prior to the pandemic.

The Navajo Community During the Pandemic

In both 2020 and 2021, the aforementioned counties maintained health outcome and health factor rankings in the bottom quarter for their respective states (County Health Rankings, 2021a; County Health Rankings, 2021b; County Health Rankings, 2021c; County Health Rankings, 2021d; County Health Rankings, 2022a; County Health Rankings, 2022b; County Health Rankings, 2022c; County Health Rankings, 2022d). While the rankings did not change from 2019, it must be recognized that rankings could not decrease as the counties were already in the bottom quarter. Additionally, the pandemic generally exaggerated hardships further influencing the social determinants of health and worsening health outcomes (Orgera, Garfield and Rudowitz, 2021).

Moreover, it is well established that the pandemic has disproportionately affected vulnerable communities (Sequist, 2020). The regular obstacles faced within the Navajo community have only been amplified by the severity of the COVID-19 pandemic. In particular, the mortality rate of COVID-19 is approximately 2.5 times higher on the Navajo Reservation than it is in the United States as a whole (Centers for Disease Control and Prevention, 2022; Navajo Department of Health, 2022). Thus, the pre-pandemic state of the social determinants of health has undoubtedly worsened throughout the duration of the pandemic.

About Project Embrace

A 501c(3) with the mission to 'increase access to health care services for all through the provision of necessary medical resources to low-income, isolated, marginalized, or low-resource communities in the Mountain West and abroad.' Project Embrace's operations consist of five key phases 1) collection and storage, 2) sanitization and refurbishment, 3) community partner research and outreach, 4) transportation, and 5) distribution (Project Embrace, 2022).

First, gently used medical technology is collected from vendors within the community and stored at our facility. Second, with the help of volunteers, the medical technology is then thoroughly cleaned, sanitized, and refurbished as necessary. Thirdly, community partners (CP) within an

identified community are contacted to gauge the need for medical technologies and requests from the CPs are collected. The devices are then assigned to a CP and loaded into a transport vehicle. Next, the Project Embrace team transports the devices to the region of the medical campaign and finally distributes the requested medical technologies to each CP. The entirety of this process from planning to execution, can be accomplished within 4 months.

When appropriate, the team will learn more about each community partner, including the adversity they and their patients face. This is essential for Project Embrace to build trust within the respective target community, this was especially the case during the pandemic. Having a strong history of working in vulnerable and low-resource settings, Project Embrace ensures that no community partner or patient will pay for the medical technologies. Indeed, Project Embrace aims to equip already effective community organizations to increase their overall efficiency by supplying experts with needed resources and technology to more urgently address the observed needs of the community.

Project Embrace's Relationship with the Navajo Community

Project Embrace was first introduced to the Navajo community in November 2018 by the Moran Eye Center's Global Outreach team. This medical campaign allowed Project Embrace to begin building a relationship with the Navajo community and showcased the need for medical technologies. The following medical campaign in 2019 was again facilitated in collaboration with the Moran Eye Center and further strengthened relationships with community partners from the previous campaign. Additionally, the 2019 medical campaign introduced Project Embrace to new regions of the Navajo Reservation and allowed for the development of new relationships.

Over the course of the past two years, Project Embrace has worked in close collaboration with NavajoStrong, a local 501c(3) organization dedicated to increasing health and wellness for the Navajo people. Project Embrace and NavajoStrong have worked closely as first responders in the Navajo Reservation during the COVID-19 outbreak (Navajo Strong, 2022). While Project Embrace works directly with hospitals and clinical settings through the provision of medical technologies, NavajoStrong specializes in working with isolated patients who often lack a household address, via the provision of care kits (clothing, food, school supplies, etc.). Both Project Embrace and Navajo Strong have a strong history of collaboration with indigenous communities making communication of healthcare needs easier. One of the greater obstacles in accessing this community is not in the funding of our programs, but rather in the relationship development with the Navajo. The coordination of both organizations has helped increase access to vital community contacts on the reservation, leading to more frequent outreach during the COVID-19 pandemic.

Methods

Overview

The aim of this evaluation is to determine if Project Embrace was successful in supporting the Navajo community through its medical campaigns facilitated between November 2018 and January 2022. Hereafter, success will be defined as increasing or maintaining a threshold of financial efficiency and the ability to adequately meet the needs of community partners (CP) for each campaign (services rendered). Both conditions must be met to deem Project Embrace's initiatives to the Navajo community as successful. The conditions will be evaluated using the following metrics determined for each medical campaign: 1) cost to facilitate, 2) quantity of medical technologies donated (QMTD), 3) total monetary value of the medical technologies donated, and 4) delivery cost per medical technology (DCMT).

Calculation of the Medical Technology Value

The device value calculated for each medical campaign is calculated by device type. For each medical technology type and subtype (i.e. adult, pediatric, bariatric), ten current market prices are collected from different manufacturers and retailers; these prices are then averaged to find the average retail price for the medical technology subtype. A 15% deduction is applied to the average retail price to account for the medical technology being pre-owned. The average pre-owned price is then used as the standard medical technology subtype value (MTSV). The MTSV is then multiplied by the distribution quantity and repeated for the quantity in each subtype. These values are then summed to return the total medical technology value for the medical campaign.

The medical technology types and subtypes (shown in parentheses) distributed during the medical campaigns includes the following:

- Indoor manual wheelchair (adult, pediatric, bariatric)
- Outdoor manual wheelchair (adult, pediatric, bariatric)
- Motorized wheelchair (adult, pediatric)
- Four-wheeled walker (adult, pediatric)
- Two-wheeled walker (adult, pediatric)
- Basic walker (adult, pediatric, bariatric)
- Single point cane (adult)
- Quad point cane (adult)

- Commode
- Toilet riser
- Shower chair
- Shower bench
- Knee scooter
- Forearm crutches (adult, pediatric)
- Basic crutches (adult, pediatric)
- Ankle brace
- Sling
- Orthopedic boot (adult, pediatric)
- Wrist brace
- Pantiliners*
- Tampons*
- Menstrual pads*

*These medical technologies were not accounted for in the calculations or reported metrics. See limitations.

Calculation of the Financial Data

The cost to facilitate the medical campaign is calculated by collecting the receipts and summing the funds used to facilitate the medical campaign. Costs are categorized by logistics, lodging, and meals. Logistics is generally the costliest category as it includes: vehicle daily rental rate, vehicle mileage rate, insurance, and fuel.

DCMT is calculated by dividing the total cost to facilitate the medical campaign by the QMTD, as shown in Equation 1.

Eq. 1 $DCMT = \frac{total \ cost \ to \ facilitate \ medical \ campaign}{total \ number \ of \ medical \ technologies \ donated}$

Adjusted DCMT is used to account for monetary support in the form of alleviating or reducing the costs of logistics, lodging, meals, or some combination thereof. Generally, this is the result of collaboration with another organization, which may alleviate or reduce certain costs. Consequently, the reported total cost to facilitate the medical campaign is lower than if collaboration did not occur. To standardize the medical campaign metrics, estimated values of the costs avoided were factored into the total cost to facilitate the medical campaign. Thus, the adjusted DCMT is calculated using Equation 2.

Eq. 2 Adjusted $DCMT = \frac{(total cost to facilitate medical campaign) + (estimated value of costs avoided)}{total number of medical technologies donated}$

Determination of the Financial Efficiency Threshold

Financial efficiency is determined by comparing the trend in the QMTD to the trend in the DCMT, or adjusted DCMT when applicable, over the five medical campaigns. Therefore, QMTD and DCMT were plotted over time within the same figure to visualize trends (Fig. 1, 2). Additionally, the QMTD per campaign was plotted separately using a scatter plot. Linear regression was performed to determine a trendline with an equation and R² value. The slope of the reported equation represents the change in the QMTD per medical campaign, and thus over time.

To deem the medical campaigns financially efficient, one of three financial conditions must be met.

- 1. The DCMT trend remains relatively constant while the QMTD displays an increasing trend.
- 2. The DCMT displays a decreasing trend while the QMTD trend remains relatively constant.
- 3. The DCMT displays a decreasing trend while the QMTD displays an increasing trend.

Determination of the Services Rendered Range

The services rendered range is defined by balancing the supply and demand of medical technologies, over a predetermined time range. Given that Project Embrace requires adequate time to prepare for a medical campaign, the minimum range for the services rendered evaluation is set to four months (16 weeks). To account for the potential to overwhelm the community, it is imperative that the supply does not exceed six months (24 weeks). Consequently, the supply of medical technologies must last between four and six months to adequately meet the community's demand, and deem Project Embrace's services rendered successful.

The information used to evaluate services rendered is sourced from in person surveys conducted with the CPs during the medical campaigns. During these surveys, the CPs were asked to estimate the time to distribute the delivered medical technologies. This information will be supplemented with information regarding the circumstance of the Navajo community, to provide insight into supply and demand changes between medical campaigns.

Results

Overview

Project Embrace facilitated two medical campaigns within the Navajo community prior to the pandemic (November 2018 and May 2019), followed by an additional three medical campaigns during the pandemic (July 2020 to January 2022). The first medical campaign, November 2018, served as a sample set to determine the demand for medical technologies within the community. The subsequent medical campaigns increased in volume and scope as the needs of the Navajo community increased. Furthermore, the latter three medical campaigns were facilitated during the pandemic, requiring a substantial increase in quantity of medical technologies donated (QMTD) (Table 1).

Medical Campaign	Medical Technology Value	Quantity of Medical Technologies	Quantity of Community Partners Worked With
November 2018*	\$401.19	20	1
May 2019*	\$2,531.14	80	1
July 2020	\$5,898.71	110	5
December 2020	\$25,363.36	288	6
January 2022	\$37,284.23	342	6

Table 1: Medical Campaign Metrics

*Pre-COVID-19 pandemic medical campaign

Financial Evaluation

As previously mentioned, the trends in both donation cost per medical technology (DCMT) and QMTD are compared to determine if the medical campaigns were financially efficient. While DCMT accounts for the costs incurred, it is also important to account for the contributions of medical campaign collaborators to standardize the metrics used to determine overall medical campaign financial efficiency. Thus, adjusted DCMT will also be used to evaluate financial efficiency.

Figure 1 visualizes the trends of DCMT and QMTD over time. Although, the DCMT of the May 2019 campaign is relatively large, the DCMT of the other campaign is fairly consistent around \$8. The QMTD displays an increasing trend as the medical campaigns grew in volume over time. Thus, the data represented in Figure 1 meet the criteria for financial efficiency under condition 1. However, the DCMT values displayed do not accurately reflect the circumstances for the November 2018 and May 2019 campaigns as DCMT values are kept artificially low through costs covered by the Moran Eye Center through subsidized lodging.

To account for the subsidized lodging, adjusted DCMT values for the two pre-pandemic campaigns were calculated. Typically, the cost of lodging in the area is estimated at \$80.00 per room per night. During the November 2018 medical campaign, the Moran Eye Center covered the cost of two rooms for one night for a value of \$160.00. Consequently, the adjusted DCMT for the November 2018 medical campaign would be \$15.50. Likewise, the Moran Eye Center covered the cost of one room for one night during the May 2019, a value of \$80.00, for an adjusted DCMT of \$12.29 (Table 2). These adjusted DCMT values for the pre-pandemic medical campaigns replaced the respective original DCMT values in Figure 2. Although the QMTD trend remained unchanged, the adjusted DCMT trend exhibits an almost exponential decay. Given the now decreasing trend in adjusted DCMT, the data visualized in Figure 2 meets financial consideration 3.

Despite the varying DCMT trends in Figures 1 and 2, in both cases the data support one of the financial conditions. Additionally, regardless of the difference in DCMT and adjusted DCMT of the November 2018 and May 2019 medical campaigns, the latter three medical campaigns demonstrate financial efficiency. On average the QMTD per medical campaign increased by 85, while maintaining a relatively similar DCMT across the three medical campaigns (Figure 3). Furthermore, the DCMT of July 2020 and January 2022 vary the least from \$7.75 and \$7.77; yet the total monetary value and QMTD increase drastically (Table 2). Conclusively, Project Embrace improved financial efficiency throughout the execution of its medical campaigns and is thus financially successful.



Figure 1: Comparison of DCMT and Total Medical Technologies Donated Over Time



^{*}Pre-COVID-19 Pandemic medical campaign

Figure 2: Comparison of Adjusted DCMT and Total Medical Technologies Donated Over Time

Table 2: DCMT and Adjusted DCMT Across Medical Campaigns

Medical	Total Medical Campaign		Adjusted Total Medical Campaign	
Campaign	Cost	DCMT	Cost	Adjusted DCMT
November 2018*	\$150.00	\$7.50	\$310.00	\$15.50
May 2019*	\$903.27	\$11.27	\$983.37	\$12.29
July 2020	\$852.10	\$7.75	N/A	N/A
December 2020	\$2,374.86	\$8.25	N/A	N/A
January 2022	\$2,657.31	\$7.77	N/A	N/A

*Pre-COVID-19	pandemic medica	l campaign
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*Pre-COVID-19 Pandemic medical campaign

Figure 3: Total Medical Technologies Donated versus Medical Campaigns

Services Rendered Evaluation

In order for Project Embrace to truly be considered successful, the organization must not only be financially efficient, but must also demonstrate the ability to adequately address the needs of the target population. This can only be accomplished through evaluating the success of the services rendered by Project Embrace. As previously mentioned, the supply must last between 16 to 24 weeks to adequately meet the demand of the Navajo community.

As shown in Table 3, the estimated time to for CPs to distribute the medical technologies provided was collected from each medical campaign's field notes. The November 2018 medical campaign is neglected as its purpose was to provide a sample set, and not to adequately meet the needs of the Navajo community. The May 2019 medical campaign exceeded the 24-week threshold, meaning the CP was overwhelmed with the QMTD and Project Embrace did not adequately meet the demand of the community. Similarly, the following three campaigns (July 2020, December 2020, January 2022) did not adequately meet the demand present, as the estimated distribution times all fell below the 16-week minimum. Thus, Project Embrace was not successful in its services rendered as it failed to meet the demand of the community in all medical campaigns evaluated.

	Quantity of	Estimated Community
	Medical	Partner
Medical Campaign	Technologies	Distribution Time
November 2018*	20	N/A**
May 2019*	80	32 weeks
July 2020	110	12 weeks
December 2020	288	6 weeks
January 2022	342	≤ 1 week

Table 3: QMTD vs Estimated Distribution Times

*Pre-COVID-19 pandemic medical campaign

**Sample set

Discussion

Supply and Triage

Outlined in the Methods portion of this paper was two conditions that needed to have been met in order for Project Embrace's initiatives to the Navajo community to have been considered successful. The first being financial efficiency which Project Embrace met under condition 3, and the second being an evaluation on services rendered. Here, Project Embrace needed to have provided an adequate amount of medical technologies that should have been distributed to patients within an appropriate timeframe of 16 to 24 weeks, which Project Embrace was not able to do. Interestingly, this comes not as a lack of effort from Project Embrace but rather because the healthcare needs of the Navajo community increased substantially. With an average increase of 85 medical technologies donated per medical campaign, the amount of medical resources supplied was not sufficient across all three pandemic campaigns (Figure 3 and Table 3).

However, per SDG Target 3.8, it is arguable that Project Embrace made strides towards increasing greater access to quality healthcare services through the provision of medical technology that was not made available otherwise. Nonetheless, even if Project Embrace was able to provide a satisfactory supply of medical technologies to the Navajo population, the increase in demand for medical technology is symptomatic of greater indicators in inaccessibility in healthcare that Project Embrace was not addressing. Certainly, the COVID-19 pandemic affected many throughout the greater United States but took an especially large toll on isolated, low-resource communities like the Navajo tribe. As the pandemic continued to progress throughout the community, extenuating protocols and procedures were deployed by the Navajo, local, and federal government to prioritize COVID-19 control, often at the expense of existing and essential healthcare services.

As spending in healthcare increased and funding tightened, the expectation to triage in healthcare settings became certain. Throughout the United States, the need to prioritize COVID-19 protocols was apparent; from increasing work hours of healthcare professionals, to allocating more ICU beds to accommodate for more cases, to prioritize spending on personal protective equipment, to expediting vaccine rollout, etc. (Tangcharoensathien et al., 2021). The consequence of needing to triage an overwhelmed system meant that certain programs and care had to be cutback. While more urbanized settings were able to handle these stresses, rural settings like the Navajo Reservation faced greater obstacles in triage, and as a result had to take more extreme measures to preserve what little care was being offered. More often than not, the first expense to be cut in Navajo settings was basic medical technologies in favor necessary COVID-19 resources. Understanding this, it is observed the that greater need for medical technology, that is no longer being made available in clinical settings, increases by patient demand.

Violence Against Indigenous Women

In addition to the strain faced by healthcare settings throughout the Navajo Reservation, certain parameters placed by local authorities further perpetuated and enabled harm to the greater community. Combined with a general increase in unemployment, the government of the Navajo Nation instituted a curfew throughout the course of the pandemic in an attempt to limit excess social exposure (Touchin and Curley, 2020). Because more denizens of the Navajo Reservation were staying at home more often and for prolonged amounts of time, the increase of harmful amounts of alcohol consumption escalated resulting in unintended harms against indigenous women.

During its last medical campaign, Project Embrace worked a local domestic violence shelter, Amá Dóó Áłchíní Bíghan, Inc (ADABI), where staff of the shelter shared the alarming fact that there has been a substantial spike in domestic violence (DV) throughout the greater reservation. Local experts attribute this to the rampant increase in alcohol consumption, and families being forced to stay together inside for longer. The increase in communal isolation, and alcoholism predictably has led to poorer mental health outcomes and, conversely, an increase in DV. This was further reinforced by ADABI through its reporting of increased clientele of indigenous women throughout the pandemic. Another important factor that plays into an increase in DV is the increased abuse of harmful substances. According to the staff at ADABI, prior to the pandemic, one of the more prevalent substances abused on the reservation was marijuana; however, as the pandemic reeked more havoc on the community, an observed increase of cocaine and methamphetamines abuse became apparent. Unfortunately, these drugs acted as an aggravating factor in the egregious nature of violence that was being reported to local community centers like ADABI.

Most cases of violence were not, and have not, been reported to local authorities as the municipalities of the Navajo community have taken a hit in funding. That coupled with a general distrust in how local law enforcement has responded to domestic disturbances, has led to many women on the reservation to not seek services. ADABI shared with Project Embrace that there has been an unsettling increase in the rate of missing indigenous women as the pandemic and curfew have wagered on. For those that do report, justice is rarely found as the Navajo court

system has been shut down due to concerns surrounding COVID-19 (Navajo Courts, 2022). Systemic failures that do not allow survivors of DV to come forward enable the cycle of violence against women on the reservation. This all comes under the continued consequences of the pandemic.

Conclusively, while Project Embrace was able to provide medical technologies to community organizations like ADABI, the needs of the Navajo community extended far past any materialsbased problems. An increase in supply came as the result to assist battered women and children in situations that otherwise were enabled and worsened by the COVID-19 pandemic. Acknowledging this, it is clear that the services rendered by Project Embrace would not have been able to sufficiently address the more urgent needs of the community even if there was a greater supply of medical technologies to donate. Donations do not stop violence against women. In order to truly "ensure healthy lives and promote well-being for all at all ages", direct acts of violence must be addressed (SDG 3).

Limitations

Due to collaborative medical campaigns with the Moran Eye Center, COVID-19 safety concerns, and funding constraints Project Embrace was limited in the geographical scope of the medical campaigns. Although the focus of the medical campaigns excluded Coconino County, AZ and San Juan County, NM, the reduced geographic scale of the medical campaigns allowed Project Embrace to further develop relationships in the other four counties within the Navajo Reservation.

The scale of the medical campaigns steadily increased throughout the four years of Project Embrace's support to the Navajo community. It is clear that the societal and economic implications of COVID-19 increased the need for, and consequently the distributed volume of necessary medical technologies. However, this increase is also a result of the Project Embrace team's maturation and growth throughout years of working with the Navajo community. The increased movement of medical technology required innovation and a better understanding of the Navajo community, which would not have been possible without the team's continual growth.

Within the timeframe of this evaluation, Project Embrace has donated a substantial quantity of menstrual products to various CPs throughout the Navajo community. However, Project Embrace does not currently have a system to attribute monetary value to menstrual products. Thus, menstrual products are neglected in the calculation of both the total value of medical technologies and the DCMT. This is due to the immense diversity in products, retail size units, and the interests of the CPs. Project Embrace hopes to implement a system for standardization of menstrual products to allow for more accurate reporting of the value of medical technologies and the DCMT.

While there is a substantial amount of data published in regards to the Navajo community, the vulnerable nature of the Navajo community reduces the prevalence of public data. Furthermore, due to the constraints of the Navajo Reservation's infrastructure and rural nature, truly representative data is extremely limited. Given the constraints of the pandemic, these issues only furthered incomplete data collection and dissemination. Consequently, the COVID-19 data

reported by organizations like the Navajo Department of Health does not accurately convey the severity of the pandemic within this community.

Recommendations

The Sustainable Development Goals were adopted as a greater call to action for the global community. To accomplish these goals requires collaboration and partnership across the private, public, and nonprofit sectors, especially in the case extenuating global circumstances. While significant strides were made towards these greater global agendas, the COVID-19 pandemic regressed the progress of these goals in ways the world is still trying to understand. Indeed, it is essential for all proponents of the SDGs to evaluate their actions during the pandemic to understand the sustainability of their impact, especially if said proponents are working with vulnerable communities like the Navajo tribe.

While it is important for nonprofits such as Project Embrace to evaluate its overall capacity to serve during an otherwise difficult time, a more critical understanding of the community's needs and obstacles surfaced during the pandemic is essential to comprehend the totality of need of the community in question. Efficiency in programming alone is not sufficient in addressing the exigences produced by the pandemic. It is recommended that nonprofits continue to operate effective programs that assist underserved populations. Likewise, it is cautioned for these same nonprofits to maintain a deeper comprehension of their target communities as the pandemic has undeniably shifted the needs of vulnerable populations. The need for nonprofits to evolve and remain dynamic towards those they serve provide a new perspective on the advancement of the SDGs in context of the pandemic. In addition, it is recommended that nonprofits should hold themselves accountable to the dissemination of accurate information, creation of solutions, and responsible advocacy of communities in need. It is imperative to understand the greater implications of the pandemic in the context of nonprofits' respective work.

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For Objective 3: Good Health and Well-Being Eye Health Management

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Abstract

The "Specially Invited Major Report on Global Eye Health" published by The Lancet Global Health pointed out that 1.1 billion people have untreated vision impairment by 2020, this number will be increased to 1.8 billion in 2050. The incidence of vision abnormalities in China is rapidly expanding and tends to be younger. Vision problems seriously affect the healthy growth of children and adolescents, which have become a public health issue of increasing concern. According to the results of a joint survey conducted by the Ministry of Education and the Ministry of Health, the incidence of myopia in China exceeds 60%, ranking first in the world, which is a threat to the health of children and adolescents as well as the sustainability of social-economic development. Refractive error is the main cause of abnormal vision development in preschool children, it is also the most common cause of amblyopia and strabismus in children. This study will explore an efficient and convenient method of ophthalmology public health screening through cross-sectional screening of vision and refractive status for children and adolescents in China. For Kaleidos, a portable optometry device, the refractive status of adolescents and children will be tested, and the influencing factors by parents will be surveyed, obtain the original test data. To compare with the diagnosis of the medical optometrist and the screening results (gold standard), analyze the reliability and validity of the Kaleidos screening results to determine whether Kaleidos can correctly classify the tested population into the corresponding myopia category, the unconditional Logistic regression model is used to conduct a binary multi-factor analysis of related influencing factors after stepwise regression, the main influencing factors were screened out, and the correlation with the prevalence was analyzed. Accurate vision test data will help the World Health Organization and domestic health agencies to allocate the limited health resources when formulating effectively and reasonably eye health hygiene strategies. The research results can also be used as the basis for the evaluation of Kaleidos screening results, which can provide information on the reliability and validity of the optometry equipment for the field of eye health and blindness prevention, and provide a new screening method for eye health management in China. If the problem of preventable early vision loss in adolescents is solved, it will play an important role in realizing the Sustainable Development Goals (SDGs203) of China and the United Nations as a whole.

Keywords: Opthalmic public health, refractive errors, screening modalities, screening tools

Introduction

Myopia Screening Models Globally

Globally, more than 253 million people are visually impaired, among them, 217 million have moderate to severe vision impairment and 36 million are blind. Up to 81% of people who are blind or have moderate or severe vision impairment are aged 50 years and above ^[1]. More than 90% of the world's visually impaired people live in low- and middle-income countries. Except in the most developed countries, cataract remains the leading cause of blindness^[2]. The prevalence of eye disease has increased steadily from 1990 to 2015, a trend which will continue at least until 2020. Vision loss is recognized as the third-most common impairment worldwide. The productivity loss due to visual impairment and the direct expense on education and recovery has been a huge burden on families, communities and the society. It has been estimated the global economic productivity loss for vision impairment would be reached to \$110 billion in 2020 without any intervention.

In 1999, WHO and IAPB initiated Vision 2020—Right to Sight, aimed at alleviating avoidable blindness by 2020, in which many NGOs, professional institutions and eye care organizations have participated. The mission of Vision 2020 is to eliminate the key causes of avoidable blindness by promoting the design, development and implementation of sustainable national-level eye care programs by the end of 2020. The three core strategies of Vision 2020 are disease control in combination with primary health care; human resources development; and deployment of infrastructure and appropriate technology. The inclusion of equitable, sustainable and comprehensive models of eye care within national health care systems is considered as the best way to realize the goals of Vision 2020.

When we can prevent a disease, we should use effective methods to prevent it, which is the primary prevention of the disease. When a disease is not yet preventable, we should detect it and treat it early, which is the main content of secondary prevention. Disease screening refers to the systematic application of some tests, examinations, or other measures in a group of people to identify some asymptomatic, undetected patients who may have a certain disease, suspicious people, or people with a high risk of developing such a disease, which is an important method to detect. The main goals of epidemiological research are controlling the occurrence and prevalence of disease and reducing disability and death, and disease screening is also intended to achieve such goals. Performing disease screening is part of epidemiological studies of diseases and can determine the occurrence or natural course of some diseases. Disease screening allows early detection of patients for early diagnosis and early treatment. Through disease screening, it is possible to identify people at high risk of suffering from certain diseases and take measures to prevent diseases from an etiological point of view as early as possible. After early detection of the disease in the population or to take treatment measures and observe the efficacy.

Refractive error is an important visual problem in children, and there is a necessity and importance for screening. Many developed countries have established routine visual acuity and refractive

error screening policies, both as part of the government health service system and as a separate operation for commercial purposes. In Sweden, vision screening is mandatory for preschool children and is repeated at ages 7 and 10 years. The European Association for Myopia Research has been established. It includes a working network that aims to combine the resources and insights of dozens of experts from seven European countries to develop regulations and policies that can be used to control the increasing development of myopia in children^[1]. The American Association for Pediatric Ophthalmology and Strabismus (AAPOS) advocates screening children for visual impairment and refractive error. They encourage trained volunteers and optometrists to perform screenings and recommend pediatric ophthalmology professionals to manage pediatric eye diseases. At the 2005 AAPOS Annual Meeting, a workshop explored the topic of working intensely to make screenings for childhood vision and refractive errors mandatory in every state. In the United States, a system of childhood eye screening has been established, with specific programs and measures varying by state, such as in Ohio, where children receive biennial eye screenings in kindergarten. In the UK, although in those areas where screening for childhood eye disease is important, every student has the opportunity to receive a vision screening at school, mass screening of vision and refraction has been declining in some regions. Some scholars are skeptical about the effectiveness of screening, and one study analyzed the effect of screening after it was discontinued and found that most of the vision loss found with screening was mild. Many children with eye disease had already received treatments when they were screened ^[2].

Although vision screening programs have been introduced to developing countries, most children still do not receive eye examinations. They usually have little access to health services, especially in rural areas. School vision screening is becoming more common in India, especially in urban areas ^[3]. Despite the high prevalence of myopia, many Southeast Asian countries other than India have not established appropriate screening measures for refractive error and vision in children. Although the visual acuity scale method is widely used as a visual acuity screening tool, the development of screening thresholds has not been fully standardized. In China, naked distance visual acuity has long been used as a monitoring indicator. However, there are certain defects in naked distance visual acuity as a monitoring indicator because it is not only affected by eye refraction but also by eye nerve adjustment ability and is related to individual mental and psychological factors. Therefore, the weak distance vision is often not equivalent to myopic refraction, and the severity of visual refraction cannot be estimated based on nor can it be based on the degree of vision loss. There is a large body of research literature on low visual acuity in primary and secondary school students in China, but there is little conferment in survey methods. Moreover, the survey methods are not uniform, and the results are poorly comparable [4-5]. Currently, there is no standardized screening system for childhood eye diseases in China. In the southern urban areas of China, 9.6% of children aged 5-15 years old have correctable visual acuity loss, 95% of which is due to uncorrected refractive errors. Although ciliary muscle paralysis detection shadowing is the basis for clinical diagnosis of refractive error and prescription of wear lenses, it is a time-consuming and interventional examination method that is not suitable for mass level screening ^[6]. Computerized automated optometry is small, light, portable, and quick to operate, which is suitable for screening at the large-scale population level. Screening children's refractive errors with this computerized automated optometry aligns with the screening principles of simplicity, speed, and ease of acceptance. Domestic and foreign scholars have also studied

the evaluation of the accuracy of computerized automated optometry. Pesudovs et al. compared the consistency of two automated optometry devices, NIDEKARF.700A and TOPCONKR-8000, with subjective optometry and found that the difference was not statistically significant. Allen et al. applied NIDEKARF.600A to compare the repeatability of the refractive state of healthy adult eyes with subjective optometry and found that the NIDEKAR series of optometers had good repeatability and high consistency with subjective optometry ^[7]. Cordonmer et al. screened 897 children for high myopia using a Retinomax handheld automated optometer with a non-ciliary muscle paralysis method. The results showed that using +1.5 D as the positive diagnostic threshold yielded good specificity (94.6%), sensitivity (70.2%), and positive predictive value (78.6%)^[8]. They concluded that non-ciliary muscle paralysis automated optometry for refraction is an effective and feasible method for screening children for hyperopia, provided that the positive threshold for screening is adjusted accordingly. Several studies have reported that students with abnormal visual acuity are about twice as likely to be recommended for further testing with glasses compared to those without glasses. This result further suggests that students who wear glasses should also participate in vision screening at school^[9]. The key point of successful correction of childhood eye disease is early detection and early treatment to avoid missing the critical period of visual development. Therefore, screening is undoubtedly an essential tool for the early detection of refractive errors ^[10]. Nicola et al. found that if screening is for detection and treatment of amblyopia, the target population should focus on preschool children; if screening is for detection and correction of refractive errors, a more appropriate screening program is for optometrists to screen school-age children. Myopia is most likely to occur and develop during elementary school, especially at 8 to 12 years. Therefore, screening at this age is considered necessary^[11].

Human Resources for Myopia Screening in Low Resource Settings

Compared with health supervision, disease prevention and control, etc, there are large differences in the number, educational background and age of grassroots vision screening practitioners in rural China. The overall grass-roots vision screening team has the phenomenon of "two lows and one high", that is, low educational background, low professional title, high age, and lack of professional talents. Personnel engaged in primary vision screening should not only possess certain professional abilities, but also have practical experience. Most of the staff engaged in vision screening at the grass-roots level are those who do not have clinical practice skills or whose qualifications do not meet the requirements of practice.

Current Situation Regarding Myopia Screening in China

According to statistics, the annual loss of GDP due to refractive errors in the world can reach 202 billion US dollars ^[12]. The world still needs a large number of optometrists and optometry technicians to meet the untreated refractive problems worldwide. The prevention and control of abnormal vision in children and adolescents has become a destiny issue related to national rejuvenation and the future of the country, a crisis issue related to national physical health, and a public issue that the people expect. In August 2018, the Ministry of Education and other eight departments jointly researched and formulated the implementation plan for the comprehensive prevention and control of children's myopia, and the "Comprehensive Prevention and Control of

Myopia in Children and Adolescents Implementation Plan" was issued. Among the goals of the plan, our country is required to control the myopia rate of 6-year-old children to about 3% by 2030, and requires medical and health institutions to establish children's vision health care files, strictly implement the national basic health service requirements for eye care and vision examinations for children aged 0-6, realize early monitoring, early detection, and early treatment, and achieve annual coverage of eye care and vision examinations rate exceeds 90% for children aged 0-6 in our country by 2019 ^[13]. The United States Preventive Services Task Force (USPSTF) also requires all children to undergo at least one vision screening between the ages of 3 and 5^[14]. Traditionally, the commonly used refraction methods in China are retinoscopy after cycloplegia and automatic refractometers on desktop computers (such as Topcon, Nidek, etc.). In the process of pediatric ophthalmology examination, the cooperation of children is very important. Many clinical examinations often fail because children do not cooperate, which may delay the diagnosis and treatment of some children with amblyopia. Among the traditional methods of refraction examination, retinoscopy is time-consuming and requires high levels of cooperation for children and professional skills of examiners. It is difficult for those without professional training to master in a short period of time. The Topcon computer refractometer also requires the good cooperation of children to obtain relatively stable and accurate results. In addition, the desktop refractor is large in size and difficult to transport. It requires a special examination room, which is inconvenient and not suitable for extensive, large-area refractive screening. An ideal screening model for children at high risk of amblyopia should be able to screen children who may have high risk factors for amblyopia from children with low vision through rapid testing, examination or other measures ^[15]. At present, various types of vision screeners are constantly on the rise. Because of their simple inspection methods, no need for mydriasis, and high reliability of results, they have been widely used around the world ^[16-18]; The screening instrument can only analyze the refractive status of children, and the screening age group is not comprehensive. There are few studies on simultaneous vision screening, pupil and interpupillary distance investigation, and gaze position status of children aged 0.6-6; The Kaleidos used in this study can not only analyze the refractive status of children, but also has a quick and simple operation. The examiner can master it without professional training. Because the instrument is far away from the child during the examination, and there are sounds and a circle of rotating bright spots, children are easy to cooperate with. In addition, it is easy to carry and reliable in inspection results. It is now widely used in children's vision screening and eye care. It can also simultaneously detect children's interpupillary distance, pupil size, gaze position and other parameters. Pupil size is closely related to visual quality, it determines the amount of external light entering the retina, can reduce the chromatic aberration caused by the cornea and lens, and can increase the depth of vision, etc. [19-23]; It has been found that pupil size in children with amblyopia is larger than that in normal non-amblyopic children ^{[24-} ^{26]}. At present, the prevalence of refractive errors in children is high. The main way to correct myopia in our country is to wear frame glasses. When optometry and fitting frame glasses, the eve position plays a guiding role when the optometrist gives the prescription for optometry. The purpose of the measurement is to make the optical center distance of the lens consistent with the pupillary distance of both eyes, and to avoid the prism effect of the lens. Therefore, the measurement of pupil, interpupillary distance, and eye position is also crucial in children's vision screening^[27].

Study Aims

To discuss more efficient and convenient ophthalmic public health screening methods. Comparing the screening results of portable barrel optometry equipment (Kaleidos) with the diagnostic results of medical optometrists (Gold Standard), analyze the reliability and validity of the Kaleidos screening results to determine whether Kaleidos can correctly categorize into the corresponding myopia category.

A total of 4 data collections were completed in this study. They were: 232 cases of data were collected in Zhangwu County, Fuxin City on April 26, 2019; 114 cases of data were collected in Xinmin City on May 16, 2019; 113 cases of data were collected in Shenyang He Eye Specialist Hospital from 29th July 2019 to August 13th 2019; 127 cases of data were collected in Zhuanghe City on November 8 2019, and total 529 cases were valid.

Materials and Methods

Study Objectives

The study subjects were students in grades 1 to 3 (aged 6-10) who enrolled in the primary schools and were designated to participate in this study, excluding students in the other grades or students aged 6-10 who did not obtain an informed consent.

Methods and Analysis

Screening Method Evaluation

The eyes of the eligible subjects will be examined, followed by non-cycloplegic computerized optometry, non-cycloplegic autorefraction and lens insertion refraction, Kaleidos (Fig 4.1) refraction and retinoscopy optometry under the ciliary muscles paralyzed in chronological sequence.


Illustration of the Use of Kaleidos



Kaleidos Being Used at Rural Community Setting

In the project, retinoscopy optometry after cycloplegia (known as mydriasis optometry) was

selected as the gold standard in the screening evaluation process, The gold standard optometry result was used as the only standard for refractive error results; and the optometry results by Kaleidos (Fig 4.2) were compared with the gold standard results to analyze the validity and reliability of screening methods.

1. Validity evaluation: indexes include sensitivity, specificity, Youden index (YI) and likelihood ratio (LR).

Table 1. 1 Classification of Screening Results

Mathada	Gold Standard			
Methods	Patients	Non-patients		
Positive	True Positive (TP)	False Positive (FP)		
Negative	False Negative (FN)	True Negative (TN)		
Total	C1	C2		

(1) Sensitivity: known as TP rate, the percentage of patients with the disease and diagnosed as positive by the screening method, reflecting the ability of the screening method to find the patient.

Sensitivit
$$y = \frac{TP}{TP + FN} \times 100\%$$

(2) Specificity: known as TN rate, the percentage of patients without disease and diagnosed as negative by the screening method, reflecting the ability of the screening method to identify non-patients.

Specificit
$$y = \frac{TN}{FP + TN} \times 100\%$$

(3) YI: screening method can discover the real patients and non-patients.

$$YI = (Sensitivit y + Specificit y) - 1$$

(4) LR: comprehensive indicators of sensitivity and specificity, including positive LR and negative LR.

$$+LR = \frac{TP}{TN} = \frac{\text{Sensitivit y}}{1 - \text{Specificit y}}$$
$$-LR = \frac{TN}{TP} = \frac{1 - \text{Sensitivit y}}{\text{Specificit y}}$$

2. Reliability evaluation: to evaluate the consistency of the results under different detection methods, the Kappa value was used as an index to evaluate the degree of consistency.

$$Kappa = \frac{P_A - P_E}{1 - P_E}$$

 P_A is the actual observed consistency rate, P_E is the expected consistency rate, the consistency of the results checked by different methods is caused by chance.

Consistency Analysis

Using different examination methods to observe subjects requires evaluating the consistency of repeated tests, if the consistency is low, it indicates that the reliability of tested results is affected by the inconsistent of repeated test results; if the consistency is high, it indicates that the repeated test results are reliable.

In the actual test, it is difficult to avoid the inconsistency of results caused by repeated examination, Kappa is used to evaluate its consistency:

Table 1.2 Consistency Evaluation by Kappa

Method 1	Method 2	Total			
	Level 1	Level 2	Level 3	- 10181	
Level 1	a1	a2	a3	Na1	
Level 2	b1	b2	b3	Na2	
Level 3	c1	c2	c3	Na3	
Total	Nc1	Nc2	Nc3	Ν	

$$Kappa = \frac{P_A \cdot P_E}{1 \cdot P_E}$$

$$P_A = \frac{\sum A}{N}$$

In the formula, A is the actual value observed by different examination methods, a1, b2 and c3 in the table.

$$P_E = \frac{\sum E}{N}$$

 P_E is the expected consistency rate, the consistency rate of the two examination results by chance, referred to as the expected rate.

In the formula, E is the expected value, taking a1 in the table as an example, its corresponding Ea1 is Na1*Nc1/N.

The Kappa value is between -1 and +1, Kappa=+1, indicating that the results of the two tests are completely consistent; Kappa=-1, indicating that the results of the two tests are completely inconsistent; Kappa=0, indicating that the results of the two observations are occurred by chance.

U test for Kappa value: the Kappa value calculated according to the actual data is a sample statistic with sampling error. Whether the calculated Kappa value comes from the population with a total Kappa value of zero requires hypothesis testing to calculate the U value:

$$U = \frac{Kappa}{S_{K}}$$

In the formula, S_{K} is the standard error of Kappa value, and the formula is:

$$S_{K} = \frac{\sqrt{P_{E} + P_{E}^{2} - \frac{\sum N_{a} N_{c} (N_{a} + N_{c})}{N^{3}}}}{(1 - P_{E})\sqrt{N}}$$

Method of Examination

The examination methods used in the project include computerized optometry, lens insertion optometry, mydriatic refraction and Kaleidos refractive error detection.

Kaleidos is a portable binocular refractometer and vision analyzer that can measure both eyes under real-life conditions. It combines high technology to fully detect refractive errors, eye deformities and eyesight defective by testing the target refraction in the range of -15D to +15D. There are no special requirements for the use of Kaleidos photorefractometer. Only need to put patients' head on the top of tube of Kaleidos, look at the red light in the tube for 3-5 seconds, save the data directly to the tablet or mobile phone, and a complete vision test report will be displayed, which can be shared with collaborators, colleagues and patients.

After test by Kaleidos, an experienced ophthalmologist examined the conjunctiva, cornea, anterior segment, iris, pupil morphology, intraocular pressure, and fundus conditions using a portable slit lamp and a direct ophthalmoscopy.

Definition of Myopia

The result of retinoscopy optometry after cycloplegia (gold standard):

any eye with spherical equivalent (SE) power >-0.5D is classified as normal or hyperopic;

any eye with SE power \leq -0.5D & > -3.0D is classified as mild myopia;

any eye with SE power ≤-3.0D & >-6.0D is classified as moderate myopia;

any eye with SE power ≤-6.0D is classified as high myopia.

According to the classification standards of true and false myopia formulated by the Chinese Ophthalmological Society in 1986, the gold standard for pseudo-myopia is that the patient with far vision is lower than normal and near vision is normal. After using atropine, myopia disappeared and the result showed normal or mild hyperopia as pseudo-myopia. The myopia diopter is not reduced or the degree of reduction is less than 0.5DS which is true myopia; myopia diopter was significantly reduced (>0.5DS), but those who did not return to normal were mixed myopia.

Kaleidos test results for normal or hyperopia, mild myopia, moderate myopia, high myopia is the same as the gold standard results.

Diagnosis of pseudomyopia by Kaleidos: Kaleidos can only detect the spherical refractive information of the subjects, and has no function of detecting pseudomyopia without pupil dilation.

Data Analysis

Analysis of Gold Standard Alternative Methods

The data analysis of this project needs to use the gold standard to classify the research subjects, dividing the population into patients and non-patients. The results could be divided into positive and negative, and the effect of screening was evaluated based on the above data.

In the actual work of eye screening, subjects usually undergo computerized optometry or lens insertion optometry first. After the above test, the results show that for the patient with myopia, dilated pupil test is carried out after the consent of subjects with myopia. According to the previous data rules, more than 95% of the people who participated in dilated pupil tests were ametropia patients diagnosed by the gold standard. The number of non-patients who received the gold standard test was less than 5%, which resulted in the inability to obtain negative diagnostic data during the final evaluation of the screening, so it was impossible to evaluate most of the indicators of the authenticity of the screening results.

Based on the above situation, in order to ensure the integrity of screening effect evaluation, attempted to explore alternative methods to the gold standard, conducted reasonable analysis on the alternative methods, and evaluated the consistency of the examination results between the alternative methods and the gold standard. The examination results of the screening method in this project are compared with the alternative method to obtain the most realistic evaluation results.

The selection of alternative methods should be based on the principle that it does not excessively increase the difficulty of actual screening or eye health examination, and computerized optometry and lens insertion optometry are preferred.

Data Analysis of Gold Standard Alternative Method

During the analysis of the gold standard alternative method, we selected 150 subjects under their consent, collected each persons' data of computerized optometry, lens insertion optometry, and retinoscopy optometry under the ciliary muscles paralyzed. There are three optometry test results, excluding the incomplete data from the above data, a total of 95-98 cases used for analysis.

Consistency Analysis of Test Results by Computerized Optometry and Gold Standard

Referring to the definition of myopia, the test results by computerized optometry and gold standard were classified as normal, mild myopia, moderate myopia and high myopia. A total of 98 cases of valid data from the consistency analysis of computerized optometry and gold standard test results, the analysis was carried out using the method of rank data consistency analysis as follows:

Computerized	Gold star	Tatal			
optometry	etry Normal Mild		Moderate	Total	
Normal	1	0	0	0	1
Mild	4	78	0	0	82
Moderate	0	4	9	0	13
High	0	0	0	2	2
Total	5	82	9	2	98

Table 1.3 Consistency Analysis of Test Results

 P_A is 0.918, P_E was 0.713, and the calculated Kappa value was 0.72. At this time, Kappa value was a sample statistic, and there was a sampling error. U test was needed, the statistic u was 9.31, and gold standard test results $U_{0.01}$ =2.58, P<0.01. It can be considered that the computerized optometry results were consistent with the gold standard test results, referred to the definition of Kappa value:

0.0-0.20 extremely low consistency (slight);

0.21-0.40 general consistency (fair);

0.41-0.60 moderate consistency;

0.61-0.80 high degree of consistency (substantial);

0.81-1 is almost perfect.

In this case, the Kappa value was 0.72, and the 95% confidence interval (CI) was (0.56, 0.87), which could be considered highly consistent.

Consistency Analysis of the Test Results by Lens Insertion Optometry and Gold Standard

A total of 95 cases with valid data were obtained from the test results of the lens insertion optometry and gold standard. The results of the consistency analysis according to the rank data were as follows:

Insertion ontomotry	Mydriasis test				
insertion optometry	Normal	Mild	Moderate	High	10181
Normal	0	0	0	0	0
Mild	4	75	0	0	79
Moderate	0	6	8	0	14
High	0	0	0	2	2
Total	4	81	8	2	95

Table 1.4 Consistency Analysis of Test Results

 P_A was 0.895, P_E was 0.722, and Kappa value was 0.62. Then the U test was performed, and the calculated statistic u was 7.86, U0.01=2.58, P<0.01. It could be considered that there was consistency and high consistency between the insertion optometry and the mydriasis test, and the 95% CI was (0.47, 0.78).

Determination of Gold Standard Alternative Method

According to consistency analysis of test results of the above computerized optometry, lens insertion optometry and the gold standard, the conclusions were all high consistent. Therefore, computerized optometry and insertion optometry used as an alternative methods to the gold standard in this project.

According to the conventional results of diopter detection, the accuracy of lens insertion optometry was higher than that of computerized optometry, and the consistency of lens insertion optometry and gold standard detection was higher than that of computerized optometry and gold standard in this test. However, the results of this test showed the opposite result. The reason was that in the experiment of exploring alternative methods, computerized optometry was used for all subjects tested after mydriasis, the data of computerized optometry before mydriasis were more close to the results of mydriasis detection, the final result shown was that the consistency of the two was higher, and there was a possibility of bias.

In the analysis of project, it was necessary to clarify which method to use for the detection of the subject after mydriasis. The gold standard alternative method needed to use the same method, so that the alternative method was more consistent and more qualified as an alternative method to the gold standard. At the same time, it was necessary to consider the actual situation of the project implementation. If the consistency of computerized optometry and lens insertion optometry was not much different from the gold standard test results, a more easier method should be selected as an alternative method.

Receiver Operating Characteristic (ROC)

Drawing the ROC Curve

In the process of drawing the ROC curve, 56 cases of valid data were used, and the result of the lens insertion refraction test was used as the standard for myopia. Non-myopia was defined as 0, and myopia was defined as 1. The value of the left and right eyes of the Kaleidos detection result, the data closest to the left side of the coordinate axis was used as variable data. Considering that the software for drawing the ROC curve does not recognize negative values, a value is added to all variable data to ensure that all variable data become positive values after conversion, and the conversion value was +4.5. Finally, when considering the best critical value, it needs to be converted again to get the real value. The ROC curve is as follows:



Square Under the ROC Curve

Variables: Kaleidos					
			95% CI		
	Standar		Lower		
Square	d error ^a	Sig. ^b	limit	Higher limit	
.930	.036	.000	.860	1.000	

Variable: Statistics can be biased. a. nonparametric assumptions b. null hypothesis: actual square = 0.5

The square under the ROC curve was 0.930, and the standard error of the square was 0.036. The Kaleidos test results were significant for myopia (P=0.000<0.05), and the 95% CI of the curve

square was (0.86, 1.00), excluding 0.5, the conclusion is consistent with the P value.

Best Screening/Diagnostic Critical Value

The ROC coordinates are as follows:

Test result variable:Kaleidos					
If Positive is less					
than or equal to ^a	Sensitivity	1-Specificity			
-1.0000	.000	.000			
.1250	.021	.000			
.6250	.042	.000			
1.1250	.063	.000			
1.3750	.104	.000			
1.8750	.125	.000			
2.3750	.188	.000			
2.6250	.208	.000			
2.8750	.250	.000			
3.1250	.333	.000			
3.3750	.500	.000			
3.6250	.667	.000			
3.8750	.771	.000			
4.1250	.875	.250			
4.3750	.958	.500			
4.7500	.979	.625			
5.2500	1.000	.750			
5.6250	1.000	.875			
6.7500	1.000	1.000			

Coordinates of a curve

a. The minimum limit value is the minimum observed test value-1, and the maximum limit value is the maximum observed test value +1. All other limits are the average values of two adjacent observational tests.

The Coordinate Information is Calculated by YI:

Test result variable:Ka	leidos			
If positive is less than c	or equal to ^a Sensitivity	1-Specificity	ΥI	
-1	0	0	0	
0.125	0.021	0	0.021	
0.625	0.042	0	0.042	
1.125	0.063	0	0.063	
1.375	0.104	0	0.104	
1.875	0.125	0	0.125	
2.375	0.188	0	0.188	

2.625	0.208	0	0.208
2.875	0.25	0	0.25
3.125	0.333	0	0.333
3.375	0.5	0	0.5
3.625	0.667	0	0.667
3.875	0.771	0	0.771
4.125	0.875	0.25	0.625
4.375	0.958	0.5	0.458
4.75	0.979	0.625	0.354
5.25	1	0.75	0.25
5.625	1	0.875	0.125
6.75	1	1	0

It can be seen from the results that when the variable is 3.875, the YI is the largest, the corresponding sensitivity is 0.771, the specificity is 1, and the detection variable value of Kaleidos is 3.875. Considering that we converted the data before, the variable value at this time is -4.5, resulting in the actual best critical value of -0.625. The actual test result of Kaleidos is not a continuous variable. Based on the actual test result, the value -0.5, which is the closest value to -0.625, can be selected as the best critical value. The -0.5 here is consistent with the critical value of the golden standard for determining myopia \leq -0.5D (\leq -0.5D is classified as myopia).

Results

total of 529 valid data were collected. Computerized optometry was selected as an alternative to the gold standard, and the Kaleidos test results were compared and analyzed by computerized optometry. The data are as follows:

Table 4.5 Kaleidos Screening Method Data Collation

Kaleidos	Computerized o	Computerized optometry		
	Myopia	Non-myopia	I Oldi	
Positive	260	112	372	
Negative	47	110	157	
Total	307	222	529	

Validity Evaluation

Sensitivity

Sensitivit
$$y = \frac{TP}{TP + FN} \times 100\% = \frac{260}{307} \times 100\% = 84.69\%$$

Specificity

Specificit
$$y = \frac{TN}{FP + TN} \times 100\% = \frac{110}{222} \times 100\% = 49.55\%$$

ΥI

$$YI = ($$
Sensitivit y + Specificit y $) - 1 = 84.69\% + 49.55\% - 1 = 0.34$

LR

$$+LR = \frac{TP}{FP} = \frac{\text{Sensitivit y}}{1 - \text{Specificit y}} = \frac{84.69\%}{1 - 49.55\%} = 1.67$$

$$LR = \frac{FN}{TN} = \frac{1 - \text{Sensitivit y}}{\text{Specificit y}} = \frac{1 - 84.69\%}{49.55\%} = 0.31$$

Reliability Evaluation

Kappa value

According to the results of the gold standard alternative method analysis, computerized optometry as the gold standard, and combined all the data collected so far for comparative analysis. The valid data were as follows:

Table 4.6 Computerized Optometry Test Result

City	Compute	Computerized optometry test results				
City	Normal	Mild	Moderate	Severe	Total	
Zhangwu	106	84	7	1	198	
Xinmin	47	56	3	0	106	
Shenyang	3	90	14	3	110	
Zhuanghe	66	43	6	0	115	
Total	222	273	30	4	529	

The Kaleidos classification results were as follows:

Table 4.7 Kaleidos Test Results

City	Kaleidos	Kaleidos test results					
City	Normal	Mild	Moderate	Severe	Total		
Zhangwu	64	129	5	0	198		
Xinmin	40	63	3	0	106		
Shenyang	3	83	21	3	110		
Zhuanghe	45	69	1	0	115		

Total 152 344 30 3	529
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The Consistency Analysis Results were as Follows:

Table	4.8	Consistency	Analysis	of	the	Test	Results	by	Kaleidos	and	Computerized
Opton	netry	/									

Kalaidaa taat raaulta	Compute				
Kaleidos test results	Normal	Mild	Moderate	Severe	Total
Normal	110	38	4	0	152
Mild	112	226	5	1	344
Moderate	0	9	21	0	30
Severe	0	0	0	3	3
Total	222	273	30	4	529

The P_Awas 0.681 and the P_E was 0.459, resulting in a calculated Kappa value of 0.41. The U test was performed on the Kappa value of the sample, and the calculated statistic u was 11.56, U0.01=2.58, P<0.01. It can be considered that the results of the insertion optometry and the results of the mydriasis test are consistent, and it is judged as moderate consistency, 95% CI was (0.34, 0.48).

Data Collection Analysis

The Kaleidos test results are used to analyze the detection of refractive errors in different regions. The data analysis is as follows:



Figure 1. 3 Detection of refractive errors in different regions

The detection rates of refractive errors by region are as follows:

Table 1.9 Detection Rates of Refractive Errors by Region

City	Zhangwu	Xinmin	Shenyang	Zhuanghe
Detection rates	67.7%	62.3%	97.3%	60.9%

The detection rate of hyperopia by region is as follows:

Table 1.10 Detection Rate of Hyperopia by Region

City	Zhangwu	Xinmin	Shenyang	Zhuanghe
Detection rates	12.1%	14.2%	2.7%	8.7%

The detection rate of refractive error and hyperopia, except for the abnormal detection rate of Myopia Treatment Center of Shenyang He Eye Specialist Hospital, the detection rate in other areas is relatively stable: the detection rate of refractive error is about 65%, and the detection rate of hyperopia is about 10%. The reason for the abnormal detection rate of Myopia Treatment Center of Shenyang He Eye Specialist Hospital is that most of the people who have a vision test detected by other ways, and there are different degrees of abnormal visual acuity, which has a selection bias.

Discussion

From the results of the detection rate of refractive errors and hyperopia, it can be seen that, except for the abnormal detection rate of Shenyang He Eye Specialist Hospital, the detection rates of other areas are relatively stable: the detection rates of refractive errors are all about 65%, the detection rates of hyperopia are about 10%.

Like other countries, China is grappling with the coronavirus disease 2019 (COVID-19) lockdown and has prepared for work from home in every possible field. There is also no denying that our children will be staying at home for longer periods of time and that they will be taught their lessons in a virtual environment for a period of time in the future. A significant difficulty would be that children would be deprived of both appropriate and regular physical activities as well as the safe and productive classroom contact that is so critical to their physical and mental well-being.^[28] In addition to the general implications on the health of the kid, it is crucial for eye care professionals to remember that children will be spending more time inside and participating in less outside activities, both of which are recognized risk factors for the beginning of myopia. Children will also spend an increasing amount of time with digital gadgets in the not too distant future. The influence of digital gadgets extends well beyond eye health, and it is now more vital than ever to raise public awareness of the potential harm that these devices might do to the developing visual apparatus of children and adolescents. There is a predicted increase in myopic refractive error, which will affect about 50 percent of the world's population by 2050.^[29] If proper precautions are not taken during the home confinement period, the present lockdown may expedite this forecast even more.

The phrase quarantine myopia is beginning to make its way into debates and discussions in the field of optometry and vision care. There has been an increase in concern over limits on community eye health initiatives, as well as travel restrictions that make it more difficult to get eye care. However, now is a better time than ever to monitor children who are at risk for myopia as well as those who have already been diagnosed with myopia, particularly progressive myopia, and to take preventative measures. It is suggested by the outcomes of this present research that Kaleidos, because of its remote operating capability as well as its high sensitivity and specificity, might be utilized to monitor myopia in youngsters. Although the ability to work remotely and hygienically is essential for monitoring myopia in the COVID-19 era, this proposed recommendation adheres to the fact that it is not only necessary but also beneficial to raise awareness among practitioners about the needs of myopic children, as well as the general public and all stakeholders^[28].

Summary of Implications for Further Work

In summary, the prospects of using smart medical platforms for remote eye disease screening mode have been unanimously optimistic by researchers who believe that smart screening platforms can be competent for eye disease screening. Many researchers believe that this model will allow more people to enjoy safe, effective, convenient and inexpensive eye disease screening services for the general population and also can reduce the workload of medical workers and improve the quality and efficiency of their diagnosis and treatment. For medical institutions and medical systems, they can increase the scope of their service radiation and help medical resources go to the community to change the imbalance of medical resource distribution. The development of this technology is new and it is still being developed and improved. Although its model accuracy is very high, the stability still needs to be further tested in practice. However, in the face of the increasingly serious eye health problems and the foreseeable increase number of patients with eye diseases worldwide. The medical and health system will inevitably be under greater pressure. The development and application of smart medicine will give us the new solution and its remarkable superiority has showed us that smart medical treatment will be the new direction of China's medical and health development.

Conclusion

In conclusion, in present study, the refraction measured from Kaleidos a portable autorefractor was shown to have a strong ability to detect myopia compared to traditional Topcon autorefractor and cycloplegic refraction. The performance of Kaleidos in detecting individual refractive error was good, as expressed by ROC curves. These findings suggested that Kaleidos could be a very useful tool for large-scale population screening in Chinese population due to its portability and remote operational usability.

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Inclusive Co-Curricular Educational Model for Implementation of Sustainable Development for Rural and Mountain Communities

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Abstract

Target 4.7 of the United Nations' 2030 Agenda for Sustainable Development aims to ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including through education for sustainable development.

This paper discusses its implementation at Utah Valley University (UVU) through an inclusive cocurricular student engaged learning (SEL) model, which provides an opportunity for students to advocate for sustainable mountain development (SMD) in Utah and elsewhere. SEL encourages students to solve real-world problems as a group, with a faculty member serving as a mentor.

Utah International Mountain Forum UIMF), a coalition of student clubs at UVU, is an extracurricular part of the model: it involves students, especially nontraditional or adult learners, in SMD activities beyond a single semester. Adult students enhance or change their careers while taking care of families. To overcome adult students' reluctance to engage in club activities, the model provides incentives, such as flexible activity schedules, integration of their experience into group efforts, and recognition at the United Nations level. Through the curricular programs, mentors build stronger ties with adult students and encourage them to join UIMF.

Since 2011, the model encourages students to contribute experiences, solicit funds, and gain recognition for SMD advocacy. Our assessment shows that students learn how to tie their own experiences to SMD, implement initiatives collaboratively, build partnerships on different levels, and then use accumulated knowledge for engagement in SMD activities beyond the semester.

Keywords: mountain communities, adult students, student engaged learning

Introduction

Sustainable Mountain Development as Part of the 2030 Agenda for Sustainable Development

On 25 September 2015, United Nations General Assembly adopted the 2030 Agenda for Sustainable Development (UN 2015), its 17 Sustainable Development Goals (SDGs) and 169

targets. The agenda represents the most comprehensive roadmap for member states for eliminating poverty, reducing inequality, promoting gender equality and ensure protection of the environment, to name a few.

Sustainable Development Goal (SDG) # 6 and SDG #15 contain three targets, which address the importance of worlds mountains for the 2030 Agenda for sustainable development (UN 2015): Target 6.6: "By 2030, protect and restore water related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes" (UN 2015: 18/35); Target 15.1: "By 2030, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements" (UN 2015: 24/35); Target 15.4: "By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development." (UN 2015: 25/35)

"Covering 27 per cent of the world's surface, mountains are key ecosystems that provide humanity with essential goods and services such as water, food, biodiversity and energy. Mountains are home to about 1.1 billion people who are among the world's poorest: half of rural mountain dwellers face food insecurity (UNSG 2019:1/18).

The importance of sustainable development in mountain regions for the first time was recognized during the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. Chapter 13 of the Agenda 21, the plan for action endorsed at the UNCED was entitled "Managing Fragile Ecosystems: Sustainable Mountain Development (SMD)." (Price, Kohler, 2013).

As a next step in recognizing world mountains at the global level, the United Nations declared 2002 as the International Year of Mountains (IYM). The IYM under the motto "We are all mountain people" provided an opportunity to raise awareness across the world on the importance of mountain regions and challenges which they experience. As a result of the IYM, 78 countries established national committees or structures to promote SMD, special mountain laws were passed in several mountain countries. Eight major global meetings associated with the IYM were held to address the needs of mountain communities, such as women, children, and indigenous people among others. (Price, 2004).

As one of the outcomes of the IYM, the Mountain Partnership (MP) was established as "a vibrant voluntary alliance of governments and organizations committed to working together with the common goal of achieving sustainable mountain development around the world." (MP n.d.-a) The MP coordinates the SMD agenda globally through 423 members (as of 1 May 2021), including intergovernmental organizations, states, such as France, Italy, Nepal, Peru, and Switzerland among them, non-governmental organizations (NGOs), companies, and academic institutions. (MP n.d.-b). The Food and Agriculture Organization of the UN (FAO-UN) hosts a secretariat of the MP in its headquarters in Rome, Italy.

As a follow-up to IYM, the UNGA Resolution "International Year of Mountains (IYM), 2002" recommended interested institutions to: 1) Join the MP; 2) support, including financially, the programs resulting from the IYM; and 3) organize on 11 December, as UN International Mountain Day (IMD), events at all levels to highlight the importance of SMD (UN 2003).

The most recent step in highlighting the importance of the SMD for the international community, on 8 December 2021, the United Nations General Assembly adopted a resolution proclaiming 2022 as International Year of Sustainable Mountain development. "...Despite the progress that has been made in promoting the sustainable development of mountain regions and the conservation of mountain ecosystems, including their biodiversity, the prevalence of poverty, food insecurity, social exclusion, environmental degradation and exposure to the risk of disasters is still increasing, particularly in developing countries, and access to safe and affordable drinking water and basic sanitation as well as to sustainable modern energy services continues to be limited." It also invited "...all Member States, organizations of the United Nations system, other international and regional organizations and other relevant stakeholders, including civil society, the private sector and academia, to observe the International Year, as appropriate, in order to increase awareness of the importance of sustainable mountain development and the conservation and sustainable use of mountain ecosystems." (UN 2021:2/2).

Partnership Between the State of Utah and the Kyrgyz Republic with Focus on the SMD Advocacy and Building a Parliamentary Model of Governance in Kyrgyzstan

Since 1999, the State of Utah and the Kyrgyz Republic built ties with each other by studying and sharing experiences of economic development as two mountain states, which are affected not only by traditional challenges from nature such as high altitude, harsh climate, environmental problems, but also the emerging ones like climate change and outmigration. As a driving force for their cooperation Utah Valley University (UVU) located in Orem, UT has partnered with the International University of Kyrgyzstan (IUK), located in Bishkek, the Kyrgyz Republic. (Abdrisaev et al 2020-b)

UVU is the largest public university in the state of Utah, enrolling over 40,000 primarily undergraduate students. It was founded in 1941 as a technical school to serve mainly local communities in mountainous Utah. UVU today under its dual mission "allows students to continue within the same institution from Career and Technical Education (CTE) certificates and associate degrees to bachelor's and master's degrees" (UVU n.d.). Thirty percent of the UVU student body represent non-traditional or adult students. Eighty-one percent of UVU students work, seventeen percent require English remediation and seventeen percent support at least one child (Tuminez 2020). Adult students represent local rural and mountain communities. Adult students are designated as learners who experience social or educational disadvantages; have interests and values different from their traditional peers (Wyatt 2011). They represent 35-40% of the student population in the U.S. and Europe (Hittepole 2015; Hauschildt 2015).

IUK has 5,000 students. It was founded in 1993 (IUK n.d). It was one of the active contributors to the IYM activities, starting from the hosting the international conference "Mountain Research –

Challenges for the 21st Century," in Bishkek, the Kyrgyz Republic in 1996 during which a proposal was made that SMD should be the theme of one of the forthcoming years. IUK also contributed to the final event of the IYM, the Bishkek Global Mountain Summit which was held in the Kyrgyz Republic during 29 October – 1 November 2002. (Price, 2004).

IUK then studied the economic model in Utah which is considered as one of the best in the U.S. to do business, and how UVU contributes to it. UVU is the largest university in Utah, which primarily serves local communities in mountainous Utah by combining both community college, as well as baccalaureate and master's degrees for students. (Abdrisaev, et al 2020-a).

UVU, in turn, was able to learn about IUK's experiences with the United Nations (UN), its contribution to Kyrgyzstan's co-sponsorship of the United Nations' initiative to celebrate 2002 as the International Year of Mountains (IUM) and its involvement with the MP and FAO-UN. In addition, both academic institutions facilitated wide-range exchanges between the State of Utah and the Kyrgyz Republic.

Minister of Foreign Affairs of the Kyrgyz Republic Mr. Askar Aitmatov visited State of Utah in 2003 and 2004 and Dr. Danielle Butler was appointed by the Ministry of Foreign Affairs of the Kyrgyz Republic and served as the Honorary Consul of the Kyrgyz Republic in the State of Utah during 2003 - 2011.

As a highlight of the bilateral ties, Utah Governor Olene Walker led a delegation of the State of Utah during a visit to the Kyrgyz Republic in August 2003 for the celebration of the 2,200th Anniversary of Kyrgyz Statehood. In reciprocity, the President of the Kyrgyz Republic Askar Akaev traveled to Salt Lake City to discuss further plans of the partnership with the State of Utah with a focus on SMD in September 2004. On the way back to the Kyrgyz Republic, he visited the United Nations headquarters to discuss the results of the visit to Utah with the Secretary General of the United Nations Kofi Annan. (OCAM 2020)

In 2006, UVU joined the Mountain Partnership (MP) under the Food and Agriculture Organization of the UN (FAO-UN), the first North American university to do so. (MP n.d.-c). This allowed UVU jointly with IUK to promote especially the SMD agenda in the State of Utah, North America and globally, including in Kyrgyzstan.

As a result, the State of Utah and UVU were visited by envoys of the Kyrgyz Republic accredited to the United States and United Nations such as: 1) The Ambassador of the Kyrgyz Republic to the United States and Canada, Her Excellency (H.E.) Zamira Sydykova during March 8th-10th, 2007. She participated at the international Conference "Women of the Mountains" co-hosted by UVU together with the Kyrgyz National Center for Development of Mountain Regions (WOMC 2007); 2) The Ambassador of the Kyrgyz Republic to the United States and Canada, H.E. Zamira Sydykova during September 15-18, 2007. VIP-guest during the visit met with Utah government leaders and UVU administrators and made a presentation to the students and faculty of UVU about the role of Kyrgyzstan in the Central Asian region; 3) The Permanent Representative of the Kyrgyz Republic to the United Nations, H.E. Talaibek Kydyrov, on March 21-22, 2013 as a

keynote speaker at the conference, titled "Climate Change and Violence: How Heating the Planet Creates Conflict and Death." In addition, VIP guest participated at the essays contest for Utah high school students on water issues; (UVU 2013-a) 4) The Ambassador of the Kyrgyz Republic to the United States of America and Canada, H.E. Muktar Djumaliev, on 3 June 2013. Ambassador Djumaliev lectured on the topic of the political reforms in Kyrgyzstan. (UIMF 2013-a; UVU 2013-b).

Utah Legislators contributed to building a Parliamentary model of governance in Kyrgyzstan by hosting: 1) On February 3rd-5th, 2007 the Speaker of the Jogorku Kenesh (Parliament) of the Kyrgyz Republic, H.E. Marat Sultanov, who visited State of Utah and UVU by an invitation from President of the Utah State Senate John Valentine. During the visit the two men agreed to pursue a number of events directed to the strengthening of relations between legislators of Kyrgyzstan and Utah; 2) The delegation of the four members of the Kyrgyz Parliament from Ata-Meken party led by Omurbek Tekebaev, who discussed strengthening bilateral ties aimed at deepening reforms in Kyrgyzstan, educational exchanges, and sustainable mountain development; 3) Mr. Kurmanbek Dyikanbayev member of the Kyrgyz Parliament from and Bishkek city's court adviser, Sultangazy Kasymov during March 4-13, 2013. During the visit guests discussed the Kyrgyz parliamentary model of governance at the UVU Center for Constitutional Studies. (UIMF 2013-b).

In reciprocity, a joint delegation of representatives from the Rocky Mountain region states visited Kyrgyzstan on October 1-5, 2007. The delegation was led by Utah State Senate President, John Valentine and included Montana Senate Majority Leader, Carol Williams. The delegation met with Kyrgyz government officials, and representatives of several NGOs, among others.

After joining the MP, UVU jointly with IUK decided to co-host under the MP umbrella the international Women of the Mountains Conferences (WOMC) as their major initiative to promote SMD in the State of Utah and North America. This project has implemented the UNGA (2003) recommendation to support, including financially, the programs resulting from the IYM. The first WOMC was held in Orem, UT in March 2007. (Rudaz 2007) As a forum to continue efforts of the 2002 "Celebrating Mountain Women" a conference was held in Bhutan. Conference organizers raised the funds to host it elsewhere. WOMCs agenda concentrated on six issues such as: 1) Transmitting Family Values, Heritage & Culture; 2) health of Women & Children; 3) education of Women & Children; 4) economic Issues of Women & Children; 5) human Trafficking and Exploitation; and 6) leadership for Women.

The first WOMC in 2007 provided an academic forum with involvement of officials from the UN, FAO-UN, the World Bank, United States (U.S.) Department of State, envoys, from four mountain states, accredited to the UN and U.S., scholars from almost all states of the Rocky Mountains region of North America including four regional MP members as well as 17 mountain states worldwide. The Kyrgyz side was represented by its Ambassador to the United States and Canada in addition to the IUK President. The conference was highlighted in the UNSG (2007:9) as contributing to "...improvement of mountain women's status globally;" and in the UNSG (2009:12) as a forum facilitating "...creation of a regional network on gender and SMD".

Methodology

Student Clubs as a Core for Inclusive Co-Curricular Engaged Learning Model for the SMD Advocacy

Since 2011 SMD advocacy activities at UVU are pursued mainly as student-driven initiatives inline with an Elective Community Engagement classification from the Carnegie Foundation for the Advancement of Teaching which UVU received in 2008 and in 2015. The classification has been the leading framework for institutional assessment and recognition of community engagement in U.S. higher education and student engaged learning (SEL) for the past 14 years (BU n.d.). They also used previously implemented, by faculty, SMD-focused activities as guiding their priorities and providing templates for their future advocacy of SMD efforts. Continued partnership with faculty and students from the Kyrgyz Republic was also an essential part of their activities.

Through SEL also known as experiential, service, or problem-based learning students can learn to exchange knowledge and resources with communities elsewhere. It provides for them in particular: Intellectual development; basic skills acquisition; moral and ethical development; social and civic responsibility; career preparation; multicultural understanding; and personal growth (Berger et al 2014).

SEL is based on four principles:

- a) Students are provided with problems to study;
- b) They study problems as a group;
- c) They have teachers as facilitators for self-learning; and
- d) They carry the responsibility for self-learning (Burch 2000).

The SEL model was implemented through student clubs as an extracurricular activity existing at UVU campus. One of the reasons for that was the fact that SMD activities often last longer than one semester and therefore are difficult to implement through academic programs. (Abdrisaev and others 2020-a).

Student clubs allow for the implementation of four SEL principles. They are important for student learning outside of the classroom, providing them opportunities to work interdependently, in groups, through mentoring experiences led by faculty (Foubert and Urbanski 2006; Logan 2008). They also encourage students to raise funds due to the club requirements to self-fund activities. (Abdrisaev and others 2020-a).

The developed-at-UVU SEL education model ensured inclusivity of student engagement in SMD advocacy by recruiting students across the campus because of a matching with the dual mission of the academic institution and professional interests of majority of them, and by incentivizing

adult students to join their traditional peers in SMD activities. It was comprised from a student clubs coalition, as its core extracurricular part with support provided by academic programs. (Abdrisaev and others 2020-a).

Structure of the Inclusive Co-Curricular SEL Model

The inclusive co-curricular SEL model is comprised from the:

- 1) Utah International Mountain Forum (UIMF), a coalition of student clubs at UVU as <u>extracurricular core;</u> and
- 2) Academic program providing support to UIMF (Abdrisaev and others 2020-a).

As per advice of Wyatt (2011) to encourage involvement of non-traditional students in activities, this model allows them to join at any time, any of the clubs of the coalition and contribute their own experiences while pursuing SMD activities (Timpson et al 2013).

Extracurricular Part of the SEL Model

While UVU (2019:6) defines a club as "A student group with a common interest or goal," which matches with the first SEL principle about identifying a problem for students to learn, the main goal of the coalition is (UIMF n.d:1), "[R]aising awareness of mountain [including in the State of Utah] sustainability topics; ...bring the public into contact with international guests and foreign dignitaries; andbringing communities together to recognize their shared mountainous heritage."

The second principle of SEL was implemented based on UVU (2019:6) requirement that clubs have "...at least six members as enrolled UVU students ,... [and] a president who is a full-time UVU student." The president of the Club/ UIMF facilitates, in the presence of the advisor, weekly group meetings to discuss implementation of activities based on a task list, which provides a scaffolding for individual student learning (Timpson et al 2013:34). Adult students as mature and experienced individuals are able to contribute to projects based on their experiences/ interests in UIMF activities for SMD advocacy and facilitate a group learning. (Abdrisaev and others 2020-a).

The implementation of the third principle of SEL was based on the UVU (2019:10) requirement that, "A Club Mentor is someone who will support, offer advice, and give help when asked or needed...." As a result, adult students could facilitate group learning and teach their peers skills to accomplish required assignments. Faculty members usually assists clubs Presidents to tie activities with the guiding lines of the MP. All group correspondences to *implement SMD-related activities only* are copied to the advisor as feedback about group learning experiences.

President(s) of UIMF/clubs or project leader (s) coordinate students' efforts to fulfill the fourth SEL principle by finishing the task list assignments. For a full implementation of the activity, the UIMF/club president, or the non-traditional student as an initiative leader with the advisors'

counsel, ensures the submissions of: a) Essays by students about finished assignments to be posted at designed by the students' UIMF web-site; b) Their own reports about how the activity benefits the MP with gaining a proper recognition from them. (Abdrisaev and others 2020-a).

The UIMF/club president, or an adult student as the initiative leader, ensures the submissions of a report about the accomplished activity to the UVU club's office to receive funds, as per requirement of UVU (2019:6), that "Registered student clubs are at a minimum funded by member dues and additional funding from the inter-club executive council."

Curricular Part of the SEL Model

Academic programs contribute to the developed model by allowing for faculty during classes to build ties with students-especially adult learners and then raise student interest in SMD advocacy. It is achieved by inviting UIMF members to speak before their peers and by providing incentives for students' involvement with clubs (Timpson et al 2013). As a result, students can gain extracredit points for becoming a member of the coalition; for writing and posting online reflective essays not only as contributors but also as observers of the SMD activities hosted by other UIMF members. (Abdrisaev and others 2020-a)

A three-credit course "Globalization and SMD," is the only academic course related to the SMD agenda. It provides incentives, especially for adult students' involvement in the UIMF activities the students as an enhancement of their education (Wyatt 2011). It is taught during spring semesters only. While the course curricula provide students an opportunity to learn theories and practices of SMD, it also teaches them practical skills to contribute to UIMF activities, and become club leaders, among other things. Each student also writes a research paper about different aspects of sustainable development in Utah or in mountain nations globally for the undergraduate student-run and reviewed journal "Youth and the Mountains" (YATM n.d.).

Results

UIMF Members Hosting the Chair of the Permanent Council of the Organization of American States (OAS) and Permanent Representative of Peru to OAS, His Excellency Harold Forsyth

The hosting by UIMF members of the Chair of the Permanent Council of the Organization of American States (OAS) and Permanent Representative of Peru to OAS, His Excellency Harold Forsyth on 3 March 2022 at UVU provides an example of the developed SEL model ability to engage students in SMD advocacy.

The visit of the dignitary to UVU's campus was organized by the UVU Office for Global Engagement. Ambassador Harold Forsyth lectured on the topic of "New Threats to Democracy in the Americas" before students largely from UVU National Security Studies program on Thursday, March 3 at 10:00am in the Library Auditorium at UVU.

A meeting of the UIMF members took place after the main lecture of Ambassador Harold Forsyth during 11:30 am -12:15pm. It was organized based on the procedure when students first make presentations advocating for SMD and their personal contributions to it and then the guest reflects on issues addressed by them. As an established tradition with the UVU Office for Global Engagement, UIMF members use this approach in hosting envoys of foreign states accredited at the United States or the United Nations and other VIP-guests including from the Kyrgyz Republic, beginning in 2013 (Abdrisaev and others 2020-a).

In their short presentations, about 3-4 minutes long, students usually address three central points: 1) The importance for the states represented by the visiting UVU dignitary to ensure that mountain communities will be in the focus of their governmental programs on sustainable development; 2) One of the ways to ensure sustainable development for mountain communities could be the implementation of SEL models in local universities and; 3) Inclusive involvement of students in those educational models and especially non-traditional students which could help local communities learn how to sustain themselves through a group educational efforts and then to help others; and they need to learn how to tie those points to their own initiatives or projects.

Dallas Karren, current President of the UIMF and a non-traditional student moderated the event in which UIMF members made presentations before Ambassador Harold Forsyth. Alitha Thompson, UIMF Vice-President, a non-traditional student and mother of 5 children spoke about UIMF accomplishments in SMD advocacy since its founding in 2011 and presented the VIP guest a folder with copies of the official United Nations documents recognizing students from UVU for their contributions to the 2030 Agenda for Sustainable Development with focus on mountain communities; also, 2013, 2016, and 2019 reports of the UN Secretary-General on sustainable mountain development and written statements co-sponsored by the Russian Academy of Natural Science and the Utah China Friendship Improvement Sharing Hands Development and Commerce, nongovernmental organizations in consultative status with the United Nations Economic and Social Council. In addition, it included 2018 and 2019 congressional records with statements of US Congressman John Curtis and US Congressman Ben McAdams.

Six other UIMF students spoke about the essence of the SEL method at UVU with the special role of non-traditional students and how SEL allowed them to study and compare status and challenges faced by mountain communities in the State of Utah, as well as India, Pakistan, and Slovenia. They also informed the guest foreign dignitary about challenges with sustainable development for mountain communities in Peru due to climate change, and how the state of Utah addresses similar challenges by developing special programs assisting local communities and families both at the state and federal levels. As one of the students shared his research results about the important role which women-leaders play in the lives of mountain communities in Yemen and in the State of Wyoming in the United States, a second student presented the impact on the lives of mountain communities in Guatemala resulting from the power of drug cartels.

While Ambassador Harold Forsyth had about 10-15 minutes left to respond to students, he was visibly surprised by the meeting and the host of issues related to mountain communities raised by students. He admitted that in his capacity as a top envoy of the mountainous nation of Peru at

the OAS he never paid attention to issues and challenges which face mountain people. As one of the outcomes, he promised to raised these issues with other envoys at the OAS who represent mountain states and to create a special caucus.

On behalf of the UIMF members Dallas Karren presented to Ambassador Harold Forsyth a special gift. The meeting was recorded by one of the UIMF members. The UIMF president submitted a report to the UVU Clubs office to win \$100 for future SMD advocacy activities.

The task list prepared by Dallas Karren with the advice from the faculty mentor included assignments divided in four groups: secretariat; logistics, speakers, and media (UIMF 2022-a). UIMF members selected assignments based on their preferences and skills three weeks before the VIP guest visit, and under the leadership of Dallas Karren they followed through on a weekly basis. During class on Sustainable Mountain Development 15-20 minutes have been dedicated to the preparations for the visit under the leadership of Alitha Thompson. In addition to presenters, five other UIMF members also contributed to preparations and hosting of the event.

Posts about UIMF members hosting Ambassador Harold Forsyth contain a leading essay written by Dallas Karren, UIMF President; copies of official United Nations documents presented to a VIP-guest; statements of all students; a link to the video of the meeting; and a task list and student reflective essays. (UIMF 2022-b)

Student Evaluation and Recognition in the Developed SEL Model.

As per Abdrisaev and others (2020), since 2011, a website (Utah International Mountain Forum | Utah Valley University (uvu.edu) informs readers about UIMF activities with a focus on SMD advocacy in the State of Utah and elsewhere. By posting such information as copies of agendas, task lists, posters, brochures, links to media, student reflective essays, etc. the website provides; a) feedback and a measure of student learning; b) templates for future activities; c) references for student recognition; and d) institutional memory of the activities. The website was designed and is maintained by students.

More than 370 posts about SMD activities on the UIMF website during November 2011 – February 2022 or 3.7 activities per month on average, demonstrate both a variety of initiatives, experiences, as well as fundraising initiatives contributed to SMD advocacy by students, including non-traditional learners, and a sustained interest from students for involvement in extracurricular activities with UIMF. Among more than 800 reflective essays posted on the website during that time about one third of them offer lessons learned by students to host and contribute in protocol, logistics, analysis, and to observe activities of their peers and raise their own and other communities' awareness in SMD. (Abdrisaev and others 2020-a)

Posts reflect student's advocacy activities for SMD contributed through such UN experiential learning initiatives as (Datta 2014):

1). The UN Academic Impact (UNAI), an initiative of the UN Department of Global Communications, which comprises more than 1300 academic institutions globally with focus to support the principles of the UN (UN n.d.) through scholarships and research. Since 2017, when UVU joined UNAI, the SEL model presents one of the main initiatives which university contributes to the implementation of the UNAI mission.

2). Model United Nations (MUN). The MUN involves students in UN activities by simulating UN bodies such as the Security Council, the General Assembly, Economic and Social Council (ECOSOC), etc. (Feldman 2016). Although MUN and the developed model are based on SEL, the latter initiative, in comparison with the former one, engages students in implementing rather than simulating SMD elsewhere, including at the forums of the UN ECOSOC on sustainable development. Moreover, UIMF members advocated for SMD during the MUN conferences.

3). Internships at the UN. Through the SEL model students gained experiences and recognition from the MP for SMD advocacy, which allowed them both to apply and compete for internships at different institutions of the UN. After becoming interns, they continue to advocate for SMD at the UN and gain more recognition for their efforts.

4). The UN International Mountain Day (IMD) observation. This educational activity was proposed by Abdrisaev and others (2020) to be added among the three mentioned above UN experiential learning initiatives. IMD as a UN activity and proper recognition for its observation is held mainly at university campuses. The IMD is affordable and beneficial especially for adult learners, many of whom are not able to visit the UN due to time or financial constraints. It could serve also as a template to develop similar models for other International Day observations established by the UN.

More than 80 posts at the website present activities in the areas of political, educational and cultural exchanges between UIMF members with different institutions and individuals from the Kyrgyz Republic.

Posts also reflect student fundraising efforts through participation at club rushes, hosting tables at UVU campus, fundraising campaigns, and applying for grants. Since 2007, both UVU and UIMF members were able to raise about \$250,000 in total for SMD advocacy. (Abdrisaev and others 2020-a).

Posts on the UIMF website serve as references for news at MP media outlets about its accomplished SMD activities. Since 2011, UVU and UIMF have been recognized 82 times (or 10 times per year) in the MP and FAO-UN news websites and 57 times (or more than seven times yearly) in the monthly MP newsletter "Peak-to peak." (Abdrisaev and others 2020-a)

Since 2015, UIMF was recognized in MPs annual reports on SMD, and as a highlight was featured twice in the United Nations Secretary Generals reports on SMD, the only student club coalition worldwide to receive such recognition (FAO-UN 2016a; FAO-UN 2019; UNSG 2016; UNSG

2019). Since 2016, the model and UIMF were highlighted by the UN ECOSOC (2016, 2017, 2018).

As a rule, recommendation letters provided for UIMF members' professional advancement, include relevant links to UIMF, MP website and UN documents.

Originality

The developed inclusive co-curricular SEL model encourages both traditional and non-traditional students to advocate for SMD in the State of Utah, North America and worldwide. They learn new professional skills, gain networking opportunities and recognition from the United Nations for contributing their own experiences, initiatives, and financial resources to the SMD implementation. As a result, the model implements Target 4.7 of the 2030 Agenda for sustainable development (UN 2015) which states: "By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality...." (UN 2015:17/35). The model does this by interaction with mountain targets 6.6; 15.1 and 15.4. UVU is the only academic institution among the 450 MP members globally which uses SEL for SMD advocacy.

Research Limitations/Implications

The developed SEL model has engaged in an inclusive way traditional and non-traditional students in the implementation of the 2030 Agenda for Sustainable Development with an emphasis on mountain communities. Non-traditional students as representatives of local communities today present more than thirty percent of the student body in the United States, Europe, and the Western world. Considering that traditional and non-traditional students have different values and interests, it will be important to conduct further study about mitigating the impact of their differences and disagreements on the implementation of SMD activities through a group effort. In addition, further research needs to be done to study the impact of a wider role of academic programs in developing the SEL model in comparison with the current approach when they serve as a supplement to the activities implemented through a student clubs coalition as its extracurricular core.

Summary and Conclusion

This paper studied experiences at Utah Valley University in advocating the SMD agenda in the State of Utah, North America and worldwide. It is achieved through an inclusive co-curricular SEL model: the model extracurricular core is the UIMF, a coalition of student clubs at UVU; the curricular part of the model provides support for the extracurricular component by recruiting more UIMF members. As an example of successful advocacy for SMD are the written analyses of student's experiences in gaining professional skills by hosting the Chair of the Permanent Council of the Organization of American States (OAS) and Permanent Representative of Peru to OAS, His Excellency Harold Forsyth.

As research demonstrates, the effectiveness of such a model are ensured by the following:

- The use of previously faculty implemented SMD-focused activities as guiding student priorities and providing templates for their future advocacy of SMD efforts.
- Continued partnership with faculty and students from the Kyrgyz Republic as an essential part of their learning activities and building professional ties.
- Inclusiveness of the model by creating incentives for non-traditional students to join their traditional peers in efforts to gain new skills, connections, and recognition from the MP by contributing own experiences, projects, and funds for the SMD advocacy.
- The use of student clubs is effective extracurricular educational tools to implement SMD activities that go beyond a regular semester. In addition, the requirement that student clubs should self-fund activities stimulate both traditional and non-traditional students to raise funds for their future SMD initiatives and advocacy campaign.
- The club's requirement for faculty to mentor, not to micromanage students enables the president of the UIMF/clubs to take on maximum responsibilities for implementing SMD activities. Non-traditional students play an important role as project leaders due to their diverse experiences, knowledge, maturity and responsibility.
- A database of comprehensive information about implemented SMD activities can help evaluate students' learning and contribution, as well as ensure institutional memory.

The SEL model empowers both traditional and non-traditional students with professional skills and knowledge through group learning and implementation of the SMD agenda. It is especially important for non-traditional student as representatives of local and mountain communities. As a result, they are becoming full-fledged contributors to the 2030 Agenda for Sustainable Development and then contribute practically to the implementation of three mountain targets in their own communities.

Acknowledgments

The current research was supported by funding from the following institutions at UVU: Office of Engaged Learning; Office for Global Engagement; Office of Student Affairs; College of Humanities and Social Sciences, College of Science, Woodbury School of Business, and the History and Political Science Department.

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Strengthening Civil Society Capacity for Education for All In Republic of Benin: The Important Role of Universities and Other Research Institutions

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Abstract

This report tends to track the Benin's progress in the implementation of SDG 4, understanding what hinders its complete achievement in terms of capacity and to recognize best practices moving forwards. It recognizes the civil society organizations as good contributors and presents their needs to address the major challenges in education sector with just eight years left to the 2030 deadline. It explores the kinds of support universities can quickly bring to civil society in terms of capacity, competence gaps filling and multi-stakeholder's engagement in education area. It develops a formalized and concrete mechanism within which University researchers and teachers work in partnership with Civil Society Organizations to create knowledge that can produce urgent and rapid solutions in education area to reach the 2030 target.

The research calls for a necessary paradigm shift in the role played by universities and other education institutions in supporting Civil Society Organizations, particularly those operating in quality education, to make them fit to educational global development agenda.

Keywords : Civil society performance, Education 2030 Agenda

Introduction

The Agenda 2030 for Sustainable Development adopted by all United Nations Member States in 2015 provides a share blueprint for peace and prosperity for people and the planet. Seventeen Sustainable Development Goals (SDGs) recognize that ending poverty and other deprivations must go hand-in hand with strategies that improve health and education, reduce inequality, and spur economic growth, all while tackling climate change and working to preserve our oceans and forests.

The achievement of development results is highly dependent upon the human and organizational capacities to effectively, efficiently, and accountably manage and implement the programmes and projects structured to deliver these results, more often in a particularly complex enabling environment. Countries and regions experience that reality differently.

In republic of Benin, this reality does not spare education sphere. Instead of the Government commitment to provide universal free and quality education, efforts are hindered by lack of capacity. Civil society still remains the best alternative for its contribution in the implementation of education policies.

However, in order to fulfil their roles, civil society organizations (CSOs) need to be strong and well-prepared with knowledge on technical topics, such as governance and organizational structure, resource mobilization, system of program management, human resource management, financial management, advocacy and communication. Universities can play a crucial role in upgrading civil society organizations.

With just eight years left to the 2030 deadline 'we must inject a sense of urgency. Achieving the 2030 Agenda requires immediate and accelerated actions by countries along with collaborative partnerships among governments and stakeholders at all levels²', stated António GUTERRES, United Nations Secretary-General, in the 2018 Sustainable Development Goals Report.

Our research, thus, explores the kinds of support universities can quickly bring to civil society in terms of capacity, competence gaps filling and multi-stakeholder's engagement in education area. The following research questions need to be addressed :

- What kind of suitable knowledge do Civil Society Organizations need to address quality education challenge in their specific environment?
- Are higher education institutions adaptive enough to address complex education challenges?
- What are the current links between Civil Society Organizations and higher education institutions?

The main objective of the research is to develop a formalized and concrete mechanism within which University researchers and teachers work in partnership with Civil Society Organizations to create knowledge that can produce urgent and rapid solutions in education area to reach the 2030 target. Particularly, the study has the following sub-objectives :

- To develop a method for rapid mapping of CSOs in education area;
- To provide a comprehensive CSOs capacity assessment tool that fits to context;
- To propose a pathway to foster the engagement of Universities in knowledge-based challenges faced by CSOs in education sphere.

Purpose

The fundamental purpose of the research is to develop cost-effective and time-bounded capacity development tools that enhance academic institutions' engagement with civil society to promote the sustainable development goal related to education.

² The Sustainable Development Goals Report, 2018

The goals in the research are to:

- provide a mechanism for tracking the Republic of Benin progress in achieving the Sustainable Development Goal in education sphere;
- highlight the quality and effectiveness of civil society participation in the promotion of education for all;
- develop a research and knowledge-based framework to enhance CSOs engagement in education 2030 Agenda.

Design/Methodology/Approach

To provide a general overview of where we stand in terms of progress made in post-2015 education arena, there should be a strategic planning process to develop targets and benchmarks for the goal, as well as details on monitoring, evaluation and reporting systems that will be used to track progress. Thus, our research draws from international best practices and from recent efforts to design post-2015 education frameworks. Preference has been given to a comprehensive and systemic tool designed by Global Campaign for Education³. That organization has set an overarching goal for education with three key objectives and eight specific targets. Each target has a set of indicators against which progress can be tracked.

Findings

Where We Stand in the Implementation of 2030 Education Agenda

What is Education 2030 Agenda?

This agenda comprises Sustainable Development Goal (SDG) 4 – "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" by 2030 – and the Education 2030 framework for Action.

This goal provides that all Members States must guarantee 12 years of free and equitable quality education for all by 2030 and allocate a minimum between 4% and 6% of their Gross Domestic Product (GDP), and a minimum between 15% and 20% of their total public budget for education. Developing countries equally committed to allocate 0.7% of their GDP to Official Development Assistance (ODA), reinforcing the support to education.

³ The Global Campaign for Education consists of a diverse and extensive group of stakeholders from around the world. Its members in more than 100 countries share a common vision and belief in the right to and the power of education.

Efforts Made by Republic of Benin

The Post-2015 Education Sector Plan (2018–2030)

The Post-2015 Education Sector Plan (2018–2030) defines inclusive education as a "process that aims to increase participation and reduce exclusion by effectively addressing the different needs of all learners. It addresses the individual educational and learning needs of all marginalized and vulnerable children and young people : street children ; girls ; children from ethnic minority groups ; children from financially disadvantaged families ; children from nomadic/refugee/displaced families ; children living with HIV or AIDS ; and children with disabilities. Inclusive education aims to ensure that these children have equal rights and opportunities in education."

The plan is based on the guidelines for inclusion established by the United Nations Educational, Scientific and Cultural Organization (UNESCO) (2005) : « [Inclusive education] involves changes and modifications in content, approaches, structures and strategies, with a common vision which covers all children of the appropriate age range and a conviction that it is the responsibility of the regular system to educate all children."

The Post-2015 Education Sector Plan (2018–2030) defines special education as all education and training activities for persons with physical, sensory or learning disabilities, or people experiencing difficulties with personal adaptation and social integration, in order to facilitate their adaptation and social integration. Benin still has special schools. These schools follow the Integration Programme for Out-of-School Minors with Learning Disabilities (PINS in French) to manage learning disabilities.

The Education Sector Plan 2018–2030 provides for strategic options for educating children with disabilities in a mainstream school environment. It also stipulates that special centres will only receive children with multiple disabilities.

The Post-2015 Education Sector Plan (2018–2030) and the National Policy on the Protection and Inclusion of Persons with Disabilities plan to provide grants to facilities developing relevant educational initiatives for children with special needs, and to organize coaching sessions for centres and facilities with relevant inclusive educational initiatives. A draft Multi-Year Partnership Agreement (2018–2021) supervised by the French Development Agency also aims to build the country's capacities to plan, implement and monitor inclusive education. Benin should also receive support to develop sectoral plans, strategies and policies for inclusive education. Finally, regarding the integration of children with special needs from remote areas, no targeted measures have been taken to address the territorial disparities that exist between departments and communes and, especially, between urban and rural areas.

The Post-2015 Education Sector Plan (2018–2030) aims to strengthen girls' access to and retention in basic education by establishing measures to promote the recruitment and retention of female teachers in rural areas. It also seeks to exempt girls from paying secondary school fees.

In addition, it aims to select texts on sexual harassment, the fight against child marriage, and other forms of violence, and to set up listening units for girls in schools.

Currently, the Post-2015 Education Sector Plan (2018–2030) aims to implement a policy of targeting interventions to educationally disadvantaged communes. This will include conducting research into the causes of low access to education in these areas and providing quality educational supplies and services in the 25 communes.

Benin's education sector is administered by three different ministries : the Ministry of Nursery and Primary Education ; the Ministry of Secondary Education and Technical and Vocational Training (which also manages the literacy subsector) ; and the Ministry of Higher Education and Scientific Research. The National Education Council helps coordinate the entire national education system, ensures compliance with the broad educational guidelines (especially for inclusive education) and helps implement the framework act on national education. It can provide opinions and formulate proposals on the pedagogy, curricula, organization and results of the education system and teacher training.

The shift towards inclusive education requires teacher training. In the transition period while all teachers in mainstream schools are gradually being trained on educating children with special needs, the Post-2015 Education Sector Plan (2018–2030) and the National Policy on the Protection and Inclusion of Persons with Disabilities plan to appoint teachers with specialized skills in specialized centres.

Education Performance Figures

Benin does not have a national education monitoring report. However, the annual Education Joint Sector Review report can be used as a tool for monitoring education. In 2019, CBO-EPT produced a voluntary national report to monitor the implementation of Sustainable Development Goal (SDG) 4 during 2016–2018. In addition, a study on the level of SDG 4 implementation in five communes in Benin was conducted in 2018.

With the specific aim of ensuring equitable and inclusive basic education for children aged 3 to 15 years, students aged 15 years and above, and students at the post-secondary level, the Post-2015 Education Sector Plan (2018–2030) identifies certain indicators, including :

- the gender parity index based on the gross enrolment rate in general, secondary and technical education
- the proportion of girls in the fields of agriculture, science and technology, and industrial science and technology
- the proportion of children with disabilities enrolled at primary school

- the dropout rate of persons with disabilities in special institutions (from 2.2 per cent in 2016 to 0 per cent between 2021 and 2030).

In its Voluntary National Review of Progress towards the Sustainable Development Goals 2018, the country has identified other indicators of inclusive education, including the parity index (rural/urban) of the gross enrolment rate in primary/secondary education. Finally, the Benin Data Portal presents some data on all levels of education, poverty, literacy and social inequalities.

Benin has abolished school fees and is carrying out the recommendations of its 2007 Educational Forum. In 2018, the net primary enrollment rate was 97 percent. Gross enrollment rate in secondary education has greatly increased in the last two decades, from 21.8 percent in 2000 to 59 percent in 2016, 67.1 percent in the case of males and 50.7 percent for females. Because of a rapid increase in the enrollment rate, the student/teacher ratio rose from 36:1 in 1990 to 53:1 in 1997 but has dropped again in the last years to 39:1 (2018). In 2018, the gross enrollment ratio in tertiary education was 12.5%.

The overall adult literacy rate is 42.4 percent (2018), significantly lower than in neighbors Togo (63.7%) and Nigeria (62%). Only 31.1% of women in Benin 15 years or older are literate, although this number increases to 51.9% for the 15-24 years old (69.8% for men).

The Human Rights Measurement Initiative (HRMI) finds that Benin is fulfilling only 77.6% of what it should be fulfilling for the right to education based on the country's level of income. HRMI breaks down the right to education by looking at the rights to both primary education and secondary education. While taking into consideration Benin's income level, the nation is achieving 96.5% of what should be possible based on its resources (income) for primary education but only 58.8% for secondary education.

The Contribution of Civil Society

For the purposes of this research, the term "civil society" is used to refer to organized groups or associations that "are separate from the state, enjoy some autonomy in relations from the state, and are formed voluntarily by members of society to protect or extend their interests, values or identities." This is the definition employed by Manor, Robinson and White in their Ford Foundation study of civil society and governance. It draws on the sociological conceptualization of civil society as a realm situated between the state and other basic building blocks of society (individuals, families and firms) (Manor, Robinson & White 1999 ; Mercer 2002 ; Edwards 2004).

A wide range of civil society organizations might be expected to be active in education. In this research we thus focused primarily on formal civil society actors operating within the national educational policy arena : non-governmental organizations, parents' associations, teachers' unions, faith-based organizations, private provider groups, and networks or coalitions. We recognize that by doing so we may have excluded forms of civil society organization that are unique to African cultural contexts, or that are located at the local or community level (Hyden 2006 ; Mercer 2003 ; Lewis 2002). One of the recommendations from our study is for further research

on the interface between formal civil society organizations in education and the local citizens, members and communities they suppose to represent.

Coalition béninoise des organisations pour l'éducation pour tous (the Beninese Coalition of Organizations for Education for All – CBO-EPT) provides tools for parents of pupils with disabilities. The Programme to Support the Inclusion of Persons with Disabilities (PAIPH) supports this group through awareness-raising and training activities. It is responsible for installing (portable) ramps and other modifications in schools. Other initiatives in favour of inclusive education carried out by CBO-EPT should also be noted. The organization organizes training for parents, teachers, inspection bodies, supervisors and school inspectors.

Other initiatives implemented by NGOs to promote girls' education have also been introduced, including exempting girls from school fees. The most effective measures have been reducing costs for families (particularly through free education) and sustained advocacy and awareness-raising activities.

Obviously, there is a need for harmonization in an education goals framework. « Often the disharmony is a result of a reporting framework that often privileges some targets and indicators above others. A new post-2015 education framework should, at a minimum, bring the two frameworks together within a unified architecture buttressed by unified reporting mechanisms and processes.

At the same time, a global goals framework should ensure that it is responsive to and reflects regional and national priorities and specificities. In this respect, it is possible to conceive of a global education agenda framed in such a way that there are common goals with some broad common targets, and which allow for regional and national modification and interpretation of targets and by implication indicators⁴.

Table 1 below presents an overarching goal for education with three key objectives and eight specific targets. Each target has a set of indicative indicators against which progress can be tracked.

⁴ Education in the Post-2015 Development Agenda - DRAFT Synthesis Report of the Global Thematic Consultation on Education

<u>Overall Goal</u> : By 2030, ensure equitable, free and inclusive quality education and lifelong learning for all

Objective 1 : By 2030, the right of every child to complete a full cycle of continuous, free, quality early childhood, primary and secondary education is fulfilled.

TARGETS	INDICATORS		
Target 1 : All children are enrolled	Number and percentage of children who are enrolled		
in school by 2020, and completing	in early childhood education		
a full cycle by 2030	Number and percentage of children who have		
	completed at least one year of free pre-primary		
	education by 2020, and by 2025.		
	Number and percentage of children who enrol in and		
	complete a full cycle of free primary education		
	Number and percentage of children completing free		
	quality secondary education		
Target 2 : By 2025, all children are	Percentage of children taught by trained and		
taught by qualified teachers who	qualified teachers, with clear and transparent		
have training in pedagogy, rights	national benchmarks for qualified teacher status		
and gender sensitivity, in an	which includes training in pedagogy, rights and		
accessible and safe environment	gender sensitivity.		
	Ratio of qualified teachers to pupils, disaggregated		
	by location (i.e. rural-urban, sub-national, district).		
	Number and percentage of educational		
	environments that have accessible, inclusive, safe		
	and adequate infrastructure and facilities for all		
	students, and are free from violence and attack.		
Target 3 : By 2030, all children	Percentage of schools with teaching and learning		
complete full cycle of inclusive	resources (i.e. textbooks) that are non-		
quality and gender sensitive	discriminatory, and are available for all students from		
education with relevant learning	the beginning of the school year.		
achievements determined through	Percentage of children in pre-primary and grades 1		
multiple measures	and 2 who are educated in their mother tongue.		
	Percentage of children who demonstrate learning		
	achievement in foundational competencies of		
	literacy, numeracy, and global citizenship (human		
	rights, sustainable development, peace, sexual and		
	reproductive health and intercultural dialogue),		
	according to national benchmarks that are relevant		
	to the student.		
<u>Objective 2</u> : By 2030, all young people and adults are literate and have the			
knowledge and skills to participate	e fully in society and the world of work.		
TARGETS	INDICATORS		

Target 4 : All young people (15-24) are fully literate by 2025, and all	Percentage of young people (15-24) with full literacy by 2020 and 2025.			
adults (15+) fully literate by 2030	Percentage of adults (15+) with full literacy by 2020, 2025 and 2030.			
	Percentage of youth and adults who have access to and complete second-chance education programmes (ensuring those who have missed out on education due to conflict, migration, gender, or other reasons, are able to gain an education).			
<u>Target 5</u> : By 2030 there is an increase of at least 50% in the	The percentage of people from different disadvantaged groups participating in further			
disadvantaged groups in quality further education (technical and	Ratio of trained teachers per student (relevant to subject)			
vocational education and training, and tertiary education), and a	Percentage of learning centres that are safe, accessible and have adequate infrastructure.			
narrowing of the gap in participation rates between more and less advantaged groups.	Percentage of young people and adults with knowledge, skills and competences for the world of work and active global citizenship			
Objective 3 : By 2030, there are ad	equate and sustainable financing and governance			
structures for education, that are t	ransparent and participatory.			
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structures for education, that are t TARGETS Target 6 : Governments calculate and allocate adequate domestic	ransparent and participatory.INDICATORSPercentage of the national budget allocated to education			
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Target 8 : Citizens, represented	Percentage of decision-making national and sub-
through formal civil society	national education sector committees and working
structures, are fully informed of and	groups that fully include civil society representatives
engaged in the development and	and teachers' representatives.
monitoring of education sector	Percentage of schools and learning centres with
policies and programmes, at	functional management committees that include
school, sub-national and national	teachers, facilitators, parents, students, and
level	community and local CSO representatives.
	Publication of education budgets, plans, data, donor
	programmes and spending information for school,
	subnational and national levels, in all national
	languages, within one month of finalisation.

TABLE 1 : An Education Goal for the Post-2015 Sustainable Development Framework⁵

Many coalition members have limited technical capacity to analyze education policies and strategies. That's why a referential tools has been proposed to serve as a guideline to Civil Society organizations' capacity development activities (Table 2).

That tool presents the targets identified in the education goal for the post-2015 sustainable development framework, as well as CSOs' strategies including advocacy, social mobilization, political and legal enforceability, development of knowledge and research, and communication. These areas of intervention are associated with a list of competences that define CSOs' professionalism. The tool is supposed to be the starting point of capacity development activities in that it can serve for capacity assessment, implementation and evaluation.

STRATEGIES BY TARGET	ADVOCACY	SOCIAL MOBILIZATI ON	POLITICAL AND LEGAL ENFORCEA BILITY	DEVELOPM ENT OF KNOWLED GE AND RESEARCH	COMMUNICA TION
Target 1 : All children are enrolled in school by 2020, and completing a full cycle by 2030.	Dialogue with communities about education as the future Raising awareness about the importance of education.	Defining mechanisms for engagement of CSOs and citizens Efforts to address the issues of	Ensuring the constitution al right to Education. Commitmen t to the realization	Conducting research on children enrollment constraints in specific areas.	Communicati ng about equity of access to education. Sensitising communities to the

⁵ Equitable, inclusive and free : a collective vision for quality education beyond 2015 ; Global Campaign for Education.

		retention and	of human	Training and	importance of
	Supporting	progression	right to	research on	education
	innovative ways	of	education.	communicati	budget work.
	for communities	Students.		on and other	
	to ensure that		A political	strategies.	Monitoring
	all children are		commitment		government
	able to access		to universal	CSOs need	expenditure
	quality		free primary	to be able to	on education
	education		education.	operate and	and using
	within a			they need to	findings to
	framework of		Enhance	be strong	inform
	national		their own	and well-	advocacy
	education		participation	prepared	activities.
	plans, in a way		in the	with	
	that links this to		developmen	knowledge	Disseminating
	advocacy.		t and	on technical	information in
			implementat	topics	time to allow
Target 2 : By	Ability to	Promoting	ion of	-	stakeholders
2025, all	appreciate the	curriculum	national	Build	to influence
children are	number of	development	education	demand for	policy
taught by	teachers	and the	sector	and	debates.
qualified	recruited and	capacity and	plans.	strengthen	
teachers who	trained	professional		country- and	Involving the
have training in	Monitoring	development	Holding	global-level	media to
pedagogy,	teaching and	of teachers	government	capacities to	maximise the
rights and	learning	and	S	collect,	visibility of
gender	materials	increased	accountable	analyze, and	research.
sensitivity, in an	deliverence in a	teacher	for their	use gender-	
accessible and	timely manner.	recruitment	policy on	and age-	
safe		and	gender.	disaggregat	
environment.		assignment in	0	ed data on	Being able to
		rural areas.		education.	generate data
			Holding		and evidence
Target 3 : By	Examines	Prevent and	government	It assists	through data
2030, all	budgets to	address	s and	non-	collection
children	assess whether	school-	donors	government	from
complete full	they benefit	related	accountable	al	communities
cycle of	men and	gender-based	to their	organisation	and analysis,
inclusive quality	women equally	violence.	commitment	s and	research and
and gender	integration of a		s and	researchers	evaluation
sensitive	gender		spending	to analyse	activities in
education with	perspective into		towards	budget	their
relevant	budget		Education	policies and	respective
learning	analysis.		for All.	to improve	countries and

achievements				budget	at the regional
determined			Ability to	processes.	and global
through multiple			understand	systems and	level.
measures.			the budget's	institutions.	
			legal and		
			institutional	Research on	
		Proactive	framework.	the effects of	
Target 4 : All	Learning and	approach to	and timing	budget	
vouna people	empowerment	improve	of the	policies on	
(15-24) are fully	across genders	school-	budget	the poor	
literate by 2025.	and age	readiness	cycle		
and all adults	aroups.	and school	oyolo.	Analyses the	
(15+) fully	3	attainment is	Analysing	allocation	
literate by 2030.		needed.	the national	and use of	
			budget and	nublic	
			allocations	resources to	
Target 5 · By	The inclusion of		to education	understand	
2030 there is an	disabled people		in relation to	the impact of	
increase of at	through		education	budgets on	
least 50% in the	physical		nolicies and	the poor	
participation of	remedial and		nlans		
people from	social support		pians.	Build the	
disadvantaged	and the			canacity of	
arouns in quality	provision of				
further	safe learning			organisation	
education	spaces for the			s in hudget	
(technical and	larger			s in buuget	
vocational	community as a			Develop	
education and	whole			budget	
training and	WHOIC:			training	
tertiary				ovportiso	
education) and				that can be	
a narrowing of				directed at	
the gap in				increasing	
narticination				the	
rates hetween					
more and less				analylical	
advantaged				anu	
aroune				auvocacy	
gioups.	1				

			capacity of	
Target 6 :	Advocacy :	Enabling local	civil society	
Governments	- towards the	communities	organisation	
calculate and	Government to	to monitor	s and	
allocate	meet the	spending on	legislatures.	
adequate	international	education		
domestic	benchmark of	both at		
finance to	spending a total	national and		
ensure	of 20% of	local levels.		
equitable, free	national budget			
and inclusive	on education,	Using		
quality	focusing at	participatory		
education and	least half of that	methods to		
lifelong learning	to basic	allow		
for all, including	education ⁶ ;	communities		
by allocating at		to monitor the		
least 20% of	- to demand	use of		
national budgets	adequate	education		
to education of	education	resources.		
which at least	financing ;			
half (10% of the		Improving		
budget) should	- to regulate	transparency		
be for basic	exorbitant	and		
education.	school fees	accountability		
	charged by the	in the use of		
	private sector ;	resources for		
		primary		
	- Raising	education.		
	strategic			
	questions on			
	education			
	financing with			
	the ministries of			
	education and			
	finance.			

⁶ Fund the Future : An action plan for funding the Global Partnership for Education, FUND THE FUTURE, GLOBAL CAMPAIGN FOR EDUCATION.

Target 7 : Donors and the international community provide increased, sustained and sufficient high- quality financing for education through overseas development assistance (ODA), including by allocating at least 10% of each donor's ODA to basic education and at least 4% of humanitarian aid to education.	Advocating for increased resources to the education sector. Increasing degree of coordination among donors, and between donors and governments.	
Target 8 : Citizens, represented through formal	Citizens'particip ation for the right to education.	Participation in design and implementatio n of national
civil society structures, are fully informed of and engaged in the	civil society participation at decentralized levels of	and local education plans Have closer contacts with
development and monitoring of education sector policies	educational governance.	communities, and they can be the bridge so that
and programmes, at school, sub-		student, parent or teacher
national and national level.		about the

	education services reach policy makers.		
	Have representatio n of the marginalised groups in their own organisations and can talk on their behalf.		

TABLE 2 : List of Competences for CSOs' Professionalization.

The Role of Universities in SDGs

This sequence of the paper draws from Wanjiku. J. Thukia's research on the role of universities in Sustainable Development Goals⁷.

According to Mr Thukia, vocational training centers and research sectors are highly recognized in few SDGs. However, the universities' boost is needed to achieve all of the SDGs (Bhowmik, 2017). At a glance, the SDGs transverse a wide range of specific sectors namely : agriculture, health, gender equality, water and sanitation, energy, industry and innovation, infrastructure, etc., and under each area, higher education institutions make a huge contribution. Whether in teaching, research, community engagement or advisory services. The uniques functions and expertise of universities are very vital for overcoming the interconnected social, economic and environmental challenges which are covered by the SDGs agenda Bhowmik, (2017). Arguably the SDGs will not be achieved without these sectors. (Selim et al.,2017) identifies the key roles of universities under four main categories as :

- Universities can address challenges of SDGs by improvising new innovations, solutions, and knowledge to curb the negative implications.
- Universities can formulate and evaluate result-based policies and establish monitoring mechanisms on progress.

⁷ Thukia, W.J. The role of universities in Sustainable Development Goals : The Erasmus program focus ; Masters Student, Department of Hospitality and Tourism Management, School of Hospitality, Tourism and Leisure Studies, Kenyatta University, jshikut@gmail.com.

• Since SDGs' accomplishment require a 'wholeness-orientation', universities are in a better position to provide professional and personal skills, capabilities to create future leaders, decision-makers, innovators, entrepreneurs and citizens with knowledge and motivation to contribute.

Universities hold a position of neutral and trusted stakeholders within society. They also have a key role in educating the public and other sectors on the SDGs and in advocating for the importance of the SDGs. Bhowmik, J. et al. (2017) resolves that the engagement of the universities towards the achievement of SDGs is broadly on the merits of research, education, operations and governance and external leadership. His work looks deeply on each contribution and recommends steps towards accomplishing them.

So Universities can contribute to tackle barriers towards the implementation of SDGs, critically that related to education by mitigating any kind of constraints as well as specific needs and policy-based difficulties.

'To contribute to the SDGs through education, universities can :

- Incorporate the SDG agenda and Education for Sustainable Development (ESD) principles into all undergraduate and graduate courses and into graduate research training.
- Offer executive education and capacity building courses for external stakeholders on SDGs and the knowledge needs to address them.
- Promote both students and community volunteering activities that address the SDGs.
- Develop exchange relationships with universities of developing countries and those that address training programs to address SDGs.

The universities can contribute to research. They :

- Support the full spectrum of research approaches needed to address the SDGs including the interdisciplinary and transdisciplinary research.
- Advocate for national support and coordination of research on SDGs.
- Support capacity building for developing countries to undertake the use of research on SDGs.
- Encourage and support researchers to engage in global research community efforts to support SGDs (such as international assessments and syntheses of the current state of knowledge.

- Map how universities' researches and research strengths align with the SDGs and identify key researchers.
- Arrange innovation challenges to address SDGs for researchers across the University and external stakeholders⁸'.

Research Limitations/Simplications

The success of the SDG Agenda depends heavily on efficient and robust monitoring of its progress. But one of the main difficulties faced in the framework of this research is the problem of access to informations, due to the lack of disaggregated data and timely, accurate and reliable standardized data. This kind of situation did not facilitate an accurate progress tracking leading, to some biais in the research results, even if they are minor.

The analysis and findings are subject to the limitations of the data used.

Then, it is commonly stated that the sustainable development goals are integrated and inclusive. They were developed on the recognition that there are inherent synergies between all the goals; they are interconnected. Successfully addressing one issue will inadvertently also tackle others. So it was not possible to deal with the battery of interrelations of the chosen topic with all of the SDGs.

Originality/Value of the Paper

This paper examines the complexity of the debate about sustainable development goals, including the implementation of the 2030 education Agenda. While drawing from knowledge produced by high rank professionals and experts, it carries out new ideas that can drive social advancement. The research proposes simple frameworks to deal with the complex system of SDG 4 and foster future collaboration on this matter.

It also provides strategic measures based, not on the traditional discourse, but rather on a short term consideration due to the close 2030 deadline.

⁸ Thukia, W.J. The role of universities in Sustainable Development Goals : The Erasmus program focus ; Masters Student, Department of Hospitality and Tourism Management, School of Hospitality, Tourism and Leisure Studies, Kenyatta University, jshikut@gmail.com

Conclusion

This research paper highlights the efforts made Republic of Benin in the implementation of 2030 education Agenda. The country has the merit of showing leadership by drafting a Post-2015 Education Sector Plan for the period 2018-2030. The Plan provides strategic options for education for all and constitutes a pathway to achieving the defined goals.

Our research has also outlined a sort of disharmony between national and international frameworks which are normally supposed to set unified targets and indicators for monitoring and reporting purpose. To quote Mr Antonio GUTERRES, Secretary-General of the United Nations, "without evidence of where we stand now, we cannot confidently chart our path forward in realizing the Sustainable Development Goals. To that end, this report also reflects on the challenges faced in the collection, processing, analysis and dissemination of reliable, timely, accessible and sufficiently disaggregated data, and calls for better evidence-based policymaking".

The civil society engagement is also noted in the implementation of the education sector plan. However, its efforts to deal with all the aspects of its mission are not well perceived due to lack of capacity and a real need of appropriate tools. To fill the gaps, education, research and innovation are essential, making Universities key contributors to achieving the goals.

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A Study on Enhancing the E-Learning and the 21st Century Competence Skills Training in Institutions of Higher Learning

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Abstract

A universal education system relies on several factors, but perhaps the most fundamental is access to education. The fundamental focus of the MDGs was expanding access to elementary education, and this theme continues in SDG4 in a slightly revised form. Enrollment rates are the most fundamental indicator of educational opportunity. Uganda has listed basic enrolment as a national indicator, despite the fact that such metrics are not utilized for the global SDG4 objectives. "Uganda Bureau of statistics Uganda report 2020" This paper used both qualitative and guantitative methods of research. The gualitative method helped in the exploration of experiences and concepts of the subject matter in detail through literature review. The research revealed that some of the modes of instruction that are used in institutions are traditional, hybrid, simulation, elearning and handouts. The respondents revealed that there is a great need to inspire and create a positive mind-set of the students and lecturers to the new mode of teaching and learning in the different institutions so as to enhance their adaptability to the e-learning systems. The paper recommended that administrators of virtual schools are encouraged to engage in more extensive professional development. In addition, policymakers are urged to respect faculty independence and refrain from intervening too closely in the educational process. Institutional investment is critical to the development of e-learning.

Keywords: e-learning, Quality, High Education, Institutions, COVID 19, Competence, employment, technical and vocational skills

Introduction

The development of Uganda's education system is the focus of a lot of interest right now. Therefore, educational institutions are extensively using technology to give another alternative of course delivery to students. As a result, educational sectors need to guarantee that these technologies are used properly within the sector itself. One of the more recently developed and widely used technologies in education is known as collaborative eLearning. This technology plays a significant part in the rise in the number of students enrolling in universities across the world, most notably in Ugandan universities, because most institutions have begun providing education in the form of learning.

In the communities, neighborhoods, and workplaces of the 21st century, having a grasp of the cultures of the globe and the capacity to communicate with people who come from a variety of

backgrounds are necessary abilities. Because students in online learning contexts have access to vastly larger networks of individuals, they are in a better position than students in traditional classroom settings to develop the aforementioned abilities. Students have a much easier time collaborating with people from all over the world and picking up knowledge from them, which leads to an increased understanding of the global character of communities in the 21st century.

It is expected of institutions of higher education that they will evolve so that they can meet the requirements of society. Because of this, institutions of higher education take on the critical duty of cultivating qualified personnel, which are essential to the functioning of society and the economy. In this environment, it is expected of individuals that when they graduate from institutions of higher education, they will have skills appropriate for the 21st century. Several studies have been conducted in order to ascertain the degree to which people in Uganda possess the skills necessary for the 21st century. The competency views of prospective teachers with reference to 21st Century abilities were investigated in the study that was carried out by Aygün et al. (2016).

Purpose

There is a consensus among institutions of higher learning that e-learning improves the standard of instruction, while few have provided concrete proof. While there is a lot of circumstantial evidence, such as student satisfaction surveys, it may not be enough to dispel the widespread skepticism that exists regarding the pedagogical benefits of online learning. It is in line with this that this project is envisioned towards enhancing e-Learning Laboratory facilities and promotion of the 21st Century Competency Skills Trainings to institutions of higher learning in Kampala in order to achieve sustainable quality education in the country.

Background Literature

The possible impact of e-learning on universities' institutional futures is now being considered and negotiated. There are still significant hurdles in certain establishments and in particular nations. The lack of trust in the pedagogical value of e-learning and the lack of investment in training faculty and staff are two of the most difficult obstacles to overcome. Institutions are pondering reorganization in light of e-learning in terms of personnel, staff development, course design, and student assistance as they work to incorporate e-learning into the fabric of their operations and get adequate financing for it. Institutions of higher learning everywhere have come to recognize the importance of hiring specialists in fields outside of academia, such as computer scientists, to complement their existing academic personnel (Elçiçek and Erdemci, 2021). Getting present faculty members on board with and invested in e-learning development is another obstacle. It is generally agreed that "staff development" is crucial to the long-term success of online education at the university level. Institutions are attempting to find a balance between faculty members and "new" employees focused on the technological components of e-learning. For the time being at least, the commercialization and internationalization of e-learning take a back seat to the day-to-day issues of implementing e-learning on college campuses.

Faculty members' reluctance to embrace e-learning may stem, in part, from their awareness of elimits learning's and the immaturity of the technologies now at their disposal. Inadequate literacy in either ICT in general or in e-learning programs, as well as a lack of time or willingness to carry out what is really an additional activity, because e-learning generally supplements rather than replaces classroom-based education (Wani, 2013).

E-learning and the information sharing it entails may also clash with the professional culture of academia, which is predicated on independence and a compensation structure that is frequently centered on research. Intellectual property rights issues might potentially be problematic. Clearly, additional e-learning advancements depend on establishing a community of e-learning adopters inside and across institutions, as well as on knowledge management methods generally pertaining to e-learning (Ndibalema, 2020). However, the real difficulties lie in expanding effective trials and disseminating and institutionalizing best methods.

Partnerships are an integral part of e-learning because they enable institutions to pool resources and learn from one another, which in turn improves educational quality, market presence, and operational efficiency. Some organizations are already working on things like e-learning infrastructure, learning management systems and apps, the development of joint programs, collaborative marketing, research collaboration, the exchange of best practices, and the distribution of hardware and software expenses. However, problems can also arise from a relationship. Whether or whether third parties should be charged for access to e-learning projects overseas for completion. Institutions of higher education seldom give strategic consideration to making their course materials available to outside parties, and they view outsourcing as having either little or no long-term benefit. There is room for improvement in how successfully partnerships and networking are utilized to disseminate information and best practices within certain industries.

Methodology Used

In this paper the researchers used both qualitative and quantitative methods of research. The qualitative method helped in the exploration of experiences and concepts of the subject matter in detail through literature review. On the other hand, the quantitative method helped the researcher get facts from the field through questionnaires and interviews that helped in making analysis thereby deducing a conclusion (Bryman, 2006).

Originality/Value of the Paper

The research presented in this paper is an original concept of the team members of Quality Education SDG4. the team followed all the ethical guidelines. In areas where information was obtained from already existing work, the researchers acknowledged the authors of the cited works. This paper specifically looks at SDG 4, quality education. It will be of great value to stakeholders as it will give an overview of what is taking place across the sector.

Findings /Discussion

Our respondents were 100 youth, 57 females and 43 males and 5 instructors, 3 males and 2 females from five different institutions of higher learning.



The research was done on 100 students and 5 institutional heads from five different institutions and the results are presented in the paragraphs. The research involved use of both primary and secondary data collection methods. Data collection was done for 4 days and our sample size was 105 (59 females 46 male) respondents in different categories as broken down below.

All the students were below the age of (25) offering diploma and certificate courses. Five heads of higher educational institutions interviewed by the team. All institutional heads that were interviewed were between the age bracket of 41 to years to 58 years of age.

The Number of Sisters or Brothers the Respondents Had

Most of the respondents had between one to five siblings that were aged between 4 to 25 years pursuing different levels of education ranging from Primary to tertiary education where the majority of our respondents were studying. The research revealed that some of the modes of instruction that are used in institutions are traditional, hybrid, simulation, e-learning and handouts. The mode of instruction commonly used changed because of the effects of COVID 19 to the hybrid mode of learning whereby both physical and e-learning were adopted by various tertiary institutions.

In addition, the respondents revealed that the challenges faced with the above mode of instruction are fewer contact hours as lecturers are distant and difficult to meet making it hard for students to interact with them. The internet network is an issue making it difficult to complete assignments and also the system slows down during examinations or tests. The data costs are high making it difficult to attend lectures sometimes. The e-learning platform has regular breakdowns due to

traffic when student's login. Finally, the traditional mode of instruction has been affected by COVID 19 and changing from traditional to digital learning is a challenge.

Possible Solutions were Shared by the Respondents that can Curb the Challenges above which Included:

The respondents revealed that there is a great need to inspire and create a positive mind-set of the students and lecturers to the new mode of teaching and learning in the different institutions so as to enhance their adaptability to the e-learning systems.

In addition, a greater percentage of the respondents noted that there is a need to identify and hire experts / technical staff to train and improve on the administrative support in a bid to help institutions get familiar with the new modes of instruction that they were going to use with the learners. It was observed that the internet connectivity was poor in most of the tertiary institutions and respondents proposed that the government should offer incentives to telecom companies so that the internet charges can become more affordable for the ordinary users. There are several labs with systems that were broken down due to poor maintenance. Regular maintenance of the digital learning gadgets to avoid system breakdown was recommended by the majority respondents. Engagement of both instructors and learners in mind-set transformation Programs to strengthen the 21st Century Competency Skills Training such as critical thinking, problem solving, and team building, among others.

According to the Respondents, All the Tools Listed Below are Used in their Institutions

Our respondents shared with our team the available tools used in teaching and they mentioned amongst them projectors, whiteboards, stationary, computers (desktops), internet servers, photocopiers and printers. It was also observed that most of the tools mentioned above are available in the institutions but unfortunately, they are not cost friendly to the learners / students. It was noticed respondents face challenges in their mode of instruction; internet charges are expensive, low Internet speed, Inadequate computers (you find that 3-4 students are sharing one computer and tools cost for example; projectors and printers.

These are Some of the Remedies that were Shared by the Respondents to Improve the Quality of Education in the Community

The institutions should make education more practical than theoretical i.e. carrying out fieldwork. In addition, promoting Mind-set changing programs to better the 21st Century Competencies to all students so as to compete for global job opportunities. There is need to put in place an enabling environment for education so that both the students and the instructors get to see improvement and development as well as enforcing e-learning through rural electrification where people can charge their e-learning devices. Finally, there should be internet connectivity within institutions of higher learning to enable students access internet easily and awareness is key and should be done first on how to use the tools to create a new trend of education and also investing in the various gadgets to make it more practical.

The Accessibility of the Internet is Moderate According to the Responses that were Gotten

These are Some of the Remedies that were Given by the Respondents on How Best the Issue of Internet can be Addressed in the Community

Zero rating the e-learning platforms e.g. zoom links embedded on the e-learning platform.

According to most of the students that were interviewed, they do not get support from their institutions regarding internet access, most of the students belong to institutional clubs in their respective schools and in addition, some students are part of the debating club society, writers club, interact club, youth alive among others and these encouraged outreaches to other institutions to help youth explore their talents further. In addition, expanding the worthy networks to remote areas and reducing the internet costs and having access to Wi-Fi and attaching minimal costs when getting to some systems like e-learning.

The key leadership roles some of the respondents took up in their respective clubs were head researcher in the debate club responsible for collecting all data regarding a specific debate topic, Secretary of the writers Club which involved creative writing and thinking, in charge of Welfare in the Youth Alive Club that involved ensuring that all members in the club were fully catered for. Some of the challenges the respondents faced during their leadership were lack of effective cooperation with all members of the club, procrastination of club activities, and conflicting royalty amongst club members among others.

These shortcomings were handled by having round table talks with all club members regarding what needs to be done and laying common strategic goals for the flourishment of the club, consulting teachers for guidance in situations that were out of hand.

From the five institutions we visited, they all seemed to have the same challenges with the exception of one. The four had computer laboratory facilities but with:

Limited access to internet connectivity due to high tariffs; incompetent computer instructors due to poor salary payment, and lack of moral / motivation from students and instructors to use ICT; theft caused by students removing components of computers during lessons; low student turn-up for training modules caused by inadequate computers in the classroom, poor and outdated / poor quality computer machines; poor 21st Century Competence Skills Training to almost all students for secondary, and University students; poor strategies for future jobs attributed to lack of mentorship, guidance and counseling to students; due to the fact that schools do not provide hands-on / technical skills training, and survival skills great number of youths fail to create jobs after school; and most students do not match career to Talent hence wrong and poor career selection.

One institution had a 50-seater computer laboratory with only chairs and tables but without any one computer they seemed to be waiting for donors and grant fees. We observed most

professionals in the community have jobs that do not match their qualifications, an issue that compromises standards of service delivery, this is attributed to mismatch of career and talent including lack of 21st Century Competence skills training to students of previous academic years. This issue has led to many challenges in the job industry and robbed most scholars of quality services. There is need for trainings to both students and instructors to have basic skills of digital e-learning and 21st Century Competence skills training.

Research Limitations/Implications

This research had limitations, which included limited resources, which prompted us to use a limited scope of survey and other methods of data collection like zoom meetings, questionnaires, phone calls, WhatsApp calls and interviews.

The team lacked previous research works on the 21st Century Competencies skills training since this is a new trend.

For reasons we did not have enough finances, high Internet rates also pivoted us to adapt the idea of making interview phone calls so as to record responses, poor network issues prompted the team to switch to personal interactions in a few institutions in order to collect some of the information that we captured and (finding study participants) some respondents/students were not fully engaged and responding to the questions that were asked. These challenges might have hindered getting the expected results of the study.

Recommendations

The following recommendations were made by the researchers after reviewing the information and the discussions:

- i. Administrators of virtual schools are encouraged to engage in more extensive professional development. There is an immediate need to provide effective professional training for administrators, which should focus on a progression from preservice training to leaders who can aid in the training of their peers. It is also\recommended that criteria for essential performance qualities stated previously be developed with\accompanying research. Furthermore, the problems highlighted in this summary are seldom addressed in academic curricula, highlighting the need for change.
- ii. Uganda's population growing fast at a rate of 3.3% by 2040 will require students to have E-Learning facilities and the 21st Century Competence Skills training so that they have technologically savvy minds, to boost the escalating numbers of unemployment, reduce numbers of school dropouts in our communities, to lead to descent formal employment and to promote non-technical skills to the students.
- iii. Policymakers are urged to respect faculty independence and refrain from intervening too closely in the educational process. Institutional investment is critical to the development

of e-learning. Above all else, policymakers and institutions need to commit to a reasonable timeline for development. Then, perhaps, e-learning will be able to bring about a positive change in higher education.

- iv. The government should provide educators all throughout Uganda the training needed to effectively implement the e-learning system. As a field, educational research is consistently undervalued (Boeren 2016). Teachers, however, play a crucial role in the educational system. They implement education policy and make it easier for people of all ages to study. Teachers, from a structural and agency viewpoint, play a crucial role in connecting students to the larger society. To fulfill the SDGs' goal of making education available and accessible to everyone, teachers must first understand what this means.
- v. To make it easier to report on both achievements and difficulties in achieving Sustainable Development Goal 4, the government ought to establish a mechanism for coordinating the tracking of all contributions made by various stakeholders, such as the private sector, CSOs, development partners, and community efforts, toward the achievement of SDG 4.
- vi. The public education system run by the government of Uganda suffers from severe funding shortages. In order to track and meet the goals of SDG4, it is necessary to invest significantly more resources in the construction of primary and secondary schools in islands and other difficult-to-reach areas, as well as in the recruitment and training of teachers, including providing incentives for and making accommodations for teacher deployment in these areas.
- vii. It is urgently necessary for the government to increase the availability of special education instructors and instructional materials in order to support inclusive education and to strengthen the capability of school administrators to properly administer and maintain special education facilities. SNE continues to place a significant amount of emphasis on specialized units and schools.

Conclusion

The system of education in Uganda has a structure of 7 years of Primary, 6 years of Secondary (divided into 4 years of Ordinary and 2 years of Advanced levels of education), and 3 to 5 years of Post-Secondary Education. Despite the long journey of study, there are increasing numbers of unemployed women, men, and youth including an escalating number of school dropouts. Statistics show that 30% of the 70% of unemployed youth in Uganda are graduates. 400,000 graduates are released annually into the job market to compete for approximately 9,000 available formal jobs. According to the UNICEF annual report 2019, Uganda, like many other African country, faces a major challenge in the provision of quality and accessible basic education. This challenge has been escalated further by the COVID 19 pandemic as a result of the drastic transition from the traditional to digital mode of learning. This project seeks to promote the enhancement of the digital learning lab facilities and promotion of the 21st Century Competency skills training in tertiary Institutions in Kampala District to reduce the escalating unemployment

rate and other related challenges. Learners and instructors from 5 tertiary institutions were interviewed through both virtual and physical interactions. Observation of highly inadequate and inefficient digital learning equipment was made which has hindered the effectiveness in both learning and mode of instruction hence the need to recommend enhancement of e-learning facilities and promotion of the 21st Century Competencies skills' training to lead to decent formal employment and promotion of non-technical skills.

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Appendices

Appendix I: Questionnaire

Introduction

Dear respondent, this is the Institute of Advanced Leadership-Uganda, we are conducting a study to evaluate the quality of education which is a component of the UN agenda 2030 which aims at ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all. This study is to evaluate the current state of education in the community so as to provide a benchmark for education related interventions. We assure you confidentiality, your personal details will not be documented anywhere. Thank You.

NO

Consent

I agree to be part of this study.

Demographics Characteristics of Respondents

YES

Gender

- Male
- Female

Age of Respondent

Less than 18	18- 25	26- 30	31-35
36- 40	41- 50	51 and above	

Highest level of Education:

- 1. Non-formal
- 2. Primary
- 3. Secondary
- 4. Certificate (professional course)
- 5. Diploma
- 6. University

7. Post graduate

How many school going persons are aged between?

- 4-5 _____ 6-13 _____
- 14-17
- 18-25
- 26+

Which one is your school and what is your year of study?

Knowledge, Attitude and Practices

Education

- 1. What mode of instruction is commonly used in institutions?
- Traditional
- Hybrid
- Simulation
- E learning
- Handouts
- Others(Specify).

2. What challenges are faced in your institution with the mode of instructions used?

.....

3. How do you cope with the above challenges?

Tools

1. What are the available tools in your institution of learning?

- Projector
- Whiteboard
- Stationary
- Computers
- Internet
- Photocopier
- Printers
- Others(specify)

.....

2. How accessible are the tools chosen above?

(1- highly inaccessible, 2- inaccessible, 3- neutral, 4- accessible, 5- highly accessible)

TOOLS	1	2	3	4	5
Projector					
Whiteboard					
Stationary					
Computers					
Internet					
Photocopier					
Printers					
Others					
(specify)					

3. Which of the above do you own? (List all that applies) 4. What challenges do you face with the accessibility of the tools? 5. What can be done to improve the quality of education in your community? 6. How accessible is the Internet in your community/institution? 7.What do you think is the best method to address the challenges of Internet access in your community/Institution? 8.Is there any support rendered regarding data in your institution/community?

Soft Life Skills

1.Do you belong to any clubs and societies in your institution?

.....

2.List down the clubs you belong to in your institution

.....

3.Do you play any leadership roles in those clubs?

.....

4.Share with us one challenging experience during your time of leadership and how you overcame it.

.....

Instituting Dynamics and Practical Experiences in K-12 Education in Underdeveloped Regions: Redefinition, Augmentation, and Diversification of Teaching Qualification to Promote Equitable Educational Access

Jihong Cai (United States)

Abstract

Sustainable Development Goals 4.c calls for sustainably supplying abundant and sufficient qualified educators. However, longitudinal studies have shown that teacher attrition has become a central issue in maintaining and recruiting qualified and talented individuals to join the industry. Many attributes contribute to the issue, while specific causes, such as the gaps in the support they need and the average payment teachers get, have lagged the sustainably delivering qualified teachers. Moreover, this issue causes more significant damage considering the disproportional distribution of educational resources, disadvantaging the underrepresented and underprivileged communities.

There are two routes to diminishing the effect and solving the problem: maintaining existing human resources and developing new sources to train and afford instructors. This paper focuses on the latter part of the solution and calls for the reconstruction of teaching qualification programs that many states and educational organizations have developed. In conjunction with Robert Sternberg's Successful Intelligence Theory, this paper analyzes the educational implication of the modification from the perspectives of students' motivation, practical and creative skills development, injecting real-world experiences in classrooms, and creating an environment that enables students to have higher exposure to practical problems. This paper further discusses how the redefined teaching qualification promotes more equitable educational access taking into consideration of the local situation, and how such a model has expansive application around the globe.

Keywords: Teaching qualification, professional education, educational access, and K-12 education

Introduction

The 17 objectives in the Sustainable Development Goals (SDGs) network, passed by the United National General Assembly in 2015, is a "blueprint to achieve a better and more sustainable future for all" (United Nations General Assembly, 2017). Goal 4 concentrates on quality education, advocating equitable educational access, and promoting elimination in education. Goal 4 aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (National Educational Foundation, 2017). The Sustainable Development Goals 4.c. urges to "substantially increase the supply of qualified teachers" by 2030 (United Nations Department of

Economic and Social Affairs: Sustainable Development, 2022). Teachers' education level is one of the essential indicators of their qualification in implying their career readiness (United Nations Statistics Division Development Data and Outreach Branch, 2022). Many institutes and governments recognize the significance of the goal and configure policies and budgets to improve their educational conditions, educational access, and educational quality. However, the development has an unbalanced reality in terms of regional differences, urban-rural distinctions, and continental discrepancies.

The unbalanced nature of educational resources has a strong regional character. Some states and regions have developed a systematic approach to recruiting educators, while others struggle to maintain the necessities. This issue is particularly prominent in less developed areas, such as underrepresented communities, where it is difficult to recruit qualified educators with the indicated requirements. It becomes more troubling and worrying when those institutes are less well-funded and supported. The school administrations need to tackle additional issues, such as infrastructural and financial problems, while maintaining the basic functionality of a school, such as ensuring students' attendance and maintaining courses offered that meet the minimum requirements of the state legislation, such as literature, sciences, and mathematics. This further aggregate the already severe educational issues, particularly hurting the existed lopsided representation of female and gender minorities, as well as racial minorities in the educational system (Paranjape, 2007; Anderson and London, 1985; Lawton, 1973; Rury and Akaba, 2014; Loeb, Kalogrides, and Horng, 2010).

Research Purpose

Limitation of educational access is a direct consequence of lacking teacher resources, worsening the attendance rate, educational quality, and student accomplishment in those nations (Deming and Figlio, 2016; Townsend et al., 2012). To tackle such a problem, countries around the globe have developed programs and approaches to endorse teachers before penetrating the profession, particularly at the K-12 level. The credentials are granted with either degree in education, completion of the training program, or record on the certification test. Nevertheless, even with constant effort in amending these programs to grant talented individuals into the educational industries maximally, teacher attrition is still a prominent issue troubling many states and their educational systems.

Teacher attrition is one of the predominant motivations for the alternation and adjustments of the current certification programs (Zhang and Zeller, 2016). Specifically, this program is particularly harmful in less developed and underrepresented communities due to the scarcity in the net sum and uneven distribution of educational resources (Ingersoll, 2004; Marilyn et al., 2011). It is more challenging for schools in those communities to attract newly qualified teachers already, and those schools are losing their current serving members. For example, in Illinois, U.S.A. alone, there are 4120.7 unfilled positions in its public-school education system, including 1703.6 teaching positions, 1242.9 paraprofessional positions, and 974.4 supporting jobs. This data only counts the officially reported state-owned public schools, and all the unfilled educational positions state-wide will be significantly more significant than the statistics provided. Among these unfilled
positions, concentrating only on Cook County, there are 2173.0 positions unfilled, and 702.9 of them are teaching positions (Illinois State Board of Education, 2021). This further illustrates the seriousness of the lack of human resources in the education system and the unbalanced distribution of educational resources.

In recent years during the pandemic, most elementary and secondary schools seek alternations to the traditional instructional structures, modifying their instructional methods from the traditional in-person instruction to either a hybrid structure or entirely online. Many professional development workshops and educational events are canceled due to health concerns. Consequences in educational resources and human resources are sources of concern. Though there has not been data supporting a significant change in teachers' turnover rate, surveys decide that teachers are more stressed during the pandemic due to the challenges in conducting teaching exercises (Theobald et al., 2020). There has been a 1% increase in both teachers' turnover rate and teachers' mobility rate in comparison to the pre-pandemic era, though it is within the rate collected in the pre-pandemic years (Goldhaber and Theobald, 2022). It is worth noting that the full impact of the pandemic may not be fully illustrated. The long-term effect of the drastic change might not unravel until later in the decade, and longitudinal research and studies are required to fully understand the impact of the pandemic caused on teacher attrition.

Teachers' Qualification: Criterion and Certifications

To determine the jurisdiction of teaching qualifications, state governments, educational organizations, and higher educational institutes have developed their systems in filtering teaching qualifications and identity if one's background is strong enough to instruct in public schools and other academies. For example, in the United Kingdom, particularly England, qualifies teacher status (QTS) is the government-recognized teaching qualification. There are several paths that one can take in order to be granted such qualification, including Postgraduate Certificate in Education (PGCE), Diploma in Education and Training (DET), School-Centered Initial Teacher Training (SCITT), and Graduate Teacher Program (GTP). Similar programs are adopted in other supernational organizations, states, provinces, and organizations, such as the United States and the European Union.

In addition to the state-recognized qualification, other professional qualifications are developed for special groups of teachers in particular subject areas, such as certificates of Teaching English as Foreign Language, Teaching English as Secondary Language, and Teaching English to Speakers of Other Languages. Furthermore, higher educational institutes and educational organizations usually offer professional development opportunities. These programs are usually designed for K-12 and higher education teachers to enrich their theoretical knowledge in a particular subject while connecting to their practical experience of daily instruction.

Degree programs in education are standard in most countries. There exist several levels of associate and academic degrees that higher education institutes offer. The most common academic degree in education includes bachelor's degrees in education, master of sciences in education, master of arts in education, master of education, doctor of philosophy in education,

and doctor of education. The specifics of the degrees vary from country to country and from college to college. Many graduate-level degrees usually concentrate on one particular aspect of education, such as educational psychology, education technologies, and educational leadership, and degrees focus on particular subjects of teaching and specific level of education.

Redefinition of Teaching Qualification: A Relative Approach

These programs may be effective in authorizing teaching lenience but not sustainability. According to a report issued by Regional Educational Laboratory Mid-Atlantic, 25% of teachers resigned from their school annually, 77% of teachers quit the profession within their first five years of entrance, and the turnover rate was the highest among middle school teachers from 2010 to 2016 (Dillon & Malick, 2020). In addition, research has captured a decreasing trend in the number of teaching candidates in comparison to a few decades ago. "Enrollment in teacher preparation remains near historic lows. Despite a 10% increase in teacher preparation enrollments between 2013–14 and 2014–15, the number of teaching candidates enrolled in 2014–15 was just one-quarter of the number enrolled in 2001–02" (Thomas and Hammond, 2016). This is not a coincidental discovery but a trend that has been observed during extended periods of studies.

This issue has become especially serious in recent years when the accumulated effect of teacher attrition has become a national-wide issue in the United States. The issue has become a central topic of concern in recent years. On top of the lack of reserved qualified teachers and teaching candidates, the unfilled positions are disadvantaging the underprivileged populations because "these teachers were disproportionately assigned to high-minority, high-poverty schools" (Darling-Hammond, 2003). The more severe impact on the underrepresented makes it more challenging to ensure equitable educational access and quality education. This problem also aggregates the lack of racial minorities and female students in certain subjects in higher education, such as science, engineering, and mathematics. Without proper guidance and support from teachers, these subjects are difficult to approach due to the nature of the subjects and the concrete materials needed before entering more advanced studies.

Many causes could attribute and contribute to the abovementioned phenomenon. Due to the complexity of the question, it is impossible to provide an exhausting list of reasons behind the scenes, and therefore, challenging to find efficacious solutions to such a problem. However, there are specific reasons that have been discussed in previous works, such as the gap between the expectations for teachers and the support they obtain and low payments (Rademacher and Eggers, 2017). In fact, in certain areas of the United States, public school, elementary, and secondary school teachers are paid 14.0% less than a decade before based on their inflation-adjusted income (National Education Association, 2021; National Education Association, 2018).

Conducted by U.S. Census Bureau, the Current Population Survey Annual Social and Economic Supplements (CPS ASEC) found that "median household income was \$67,521 in 2020, and \$69,560 in 2019, and median earnings of men is \$61,417 and \$50,982 for women who worked full-time" (Shrider et al., 2020; Irwin et al., 2021). A report on the Condition of Education 2021

conducted by the Institute of Education Science under the U.S. Department of Education determined that the average income for public school teachers who has less than ten years of teaching experience is less than \$50,000, which is remotely below the average. Only the instructors who have worked in a school for more than 20 years meet is above the median household income.

This is a direct indication that schoolteachers are earning significantly less than their peers working in industries regardless of other dissatisfactions reported by both parties, which signifies that it is more challenging for teachers to support their families financially than an average salary person. Despite its undeniable contribution of the occupation to the world, many talented individuals quit their job due to financial considerations. It is worth noting that this is only a limited analysis of this issue, and the data only refers to the situations in the United States. Other states and regions may have unique and distinct issues regarding human resources in education.

The deep reasons teachers quit their jobs are complicated and can be attributed to variegated causes. Studies on horizontal compactions or case studies on this topic could help elaborate on the explanation and discover the underlying justifications. These studies could be valuable in solving the issue of sustaining talented individuals in the educational systems. Regardless of the causes, the significant percentage of teachers leaving their jobs or mobilizing between institutes is surprising, while significant indicators signifying the inefficient utilization of educational resources in training and certifying individuals, where under a quarter of educational funding and other materials in human resource development are applied effectively to produce sustainable outcomes, notwithstanding the progressive upsurge in the education funding in many countries. Due to the complexity of the issue, it is hard to develop an exhausted list of attributions for the issue, while it is certain that the current system of recruiting educators could be optimized and potentially reduce the administrative costs on the related issues.

On the other hand, by setting up a systematic approach to training teachers in mostly lecturediscussion settings or the professional qualification program, the system declines those who are not weaponed with the certifications. In particular, these programs reject a wide range of talented individuals with professional or industrial experience entering the field and inspire young citizens to pursue and explore the related subjects, primarily abstract and creative ones. This mainly refers to applied subjects, such as engineering, technologies, sciences, as well as performative and visual arts. Moreover, with industry and professional backgrounds, instructors can relate their practical experience in the educational setting to set up real-world motivating cases where students can learn factual knowledge in addition to transferable skills and reasoning capabilities that they may apply in the future career and academic world.

In addition, educational background alone does not comprehensively reflect one's ability to deliver content for the pupils, especially taking practical and creative skills into the equation. For example, classically trained instructors might incorporate the educational theories they learned in the universities and training programs into their classrooms, and many of the techniques have pedagogical benefits. The method is instructional, but it might not reflect practical worlds where students can share and be motivated to investigate. Therefore, even though these materials might

be educationally significant, failing to appeal to students may create deeper motivational problems that have long-term effects while failing to facilitate learning and encouraging individuals to become lifelong learners in the long run, which is one of the core aims for Goal 4.

Therefore, a generalized inclusive definition of teaching qualifications is urgent for facilitating students' learning experience in many levels of K-12 education, where the goal is to cultivate students learning habits, introduce students to the general concepts in the subject, and facilitate the learning experience and motivation of the individuals in all grade levels, which inspire students to pursue a career or future education of the subject of their choice that they enjoy. This is especially important for junior and senior students who are preparing and deciding their postsecondary path, bridging the gap between high school curricula and higher educational ones, as well as the problems one might face in their work.

A relative approach is required for consideration to further increase the compatibility and accessibility of the redefined educational resources. The qualification of an educator should not be defined universally where a test or a degree sets the bar for every instructor through high-stakes tests, regardless of the local situation. In the area where educational resources are adequate, the qualification could be more rigorous, whereas, in those regions where only scared resources exist, the qualification should be more adaptive and flexible and meet the minimum number of local requirements. Therefore, such a framework allows and encourages a more accessible and equitable distribution of human resources in education and promotes teachers to support those impoverished areas with urgent educational demands. Of course, this argument does not suggest that the teacher training program is unnecessary. On the contrary, it encourages more talented individuals to enter the industry and, therefore, could have a higher potential in pursuing higher training and education in the field, such as educational leadership, curriculum and instruction, educational technologies, and equity in education.

Such modification also provides students with the practical meaning of individual subjects that they will potentially pursue as a major or minor in future education, promoting a more eager, hungry, and diverse student body and representation in transition to higher and professional education, and consequently contributing to the academic world and industrial world in cultivation of educated scholars and well-trained skilled workers and innovators. This is particularly useful in fostering students' learning in junior or senior years when they are preparing for their future academic and careers and can be applied to facilitate students' skills and interest development in general. Furthermore, by implementing and incorporating real-life problems in an instructional setting, students can exercise their practical and creative skills, facilitating their success (Sternberg, 2016; Sternberg, 2018).

Reconstructing Teaching Certification in K-12 Systems

As students continue their K-12 education, students will be increasingly exposed to a diverse range of concepts in an enlarging set of subjects. Students face major choices when they approach their senior year of high school: whether to pursue further education in higher education institutes to obtain a professional or academic degree on a specific subject or start their career

directly after graduation. In many countries, especially those with twelve years of compulsory school attendance laws, this is the first time the students will be able to make a significant decision that may alter their future life path (National Education Association State Education Practices, 2018). Students might have different considerations before reaching a conclusion, while regardless of their decision, one needs to determine the focus of their next step in life, namely, career path or academic concentration. According to John Dewey's pragmatist educational philosophy, which pinpoints personal experience as a primary factor for one to shape their reasons and decisions, the determination students will make by the end of their K-12 education will be heavily influenced by their learning experience and inspirations from their K-12 instructors and administrators (Backe, 1999).

In many cases, the comprehension of the general picture of a subject and their intuitive idea of preference is dependent on their experience in K-12 classrooms, particularly the ones in their junior and senior year of high school. More importantly, the K-12 years are precisely the times when students gain their psychological maturity and develop a set of critical thinking and learning skills, in addition to the formation of their understanding of the world in general. Therefore, it is imperative for K-12 educators to be encouraging, inspiring, motivating, and inviting.

Current K-12 education providers are initialized to be closely aligned with particular curricula, usually from state standards, Common Core State Standards Initiative, or educational organizations, such as A-level from Cambridge Assessment Group, Advanced Placement from College Broad, and IB curricula. The curriculum is established at the school district level, supervised by the board of education and superintendent, and executed by academic principles and instructors. The curricula usually have their corresponding standardized exam in assessing the educational result, and the syllabus is designed closely to assist students in passing and achieving excellency in those exams. Consequently, instructors plan their lessons in close alignment with those syllabi and the exam criterion or the equivalent state-regulated high school graduation exams, such as HiSET, GED, and TASE (US HSE Credential) (ETS EiSET, 2022).

Many educators who are qualified to teach according to the regulations do not have extensive industrial experience, nor do they have extensive experience in academia. It is not to deny their potential in delivering inspiring lessons. However, the qualification programs do not necessarily reflect the reality of teaching and learning in the classroom setting, where teachers have complete control over their classroom in accordance with the school curriculum following the required syllabi. Therefore, without practical exposure themselves, it distances what students learn from what is useful in a real-life setting. Educational scholars recognize the seriousness of lacking practical knowledge in the currently imposed curricula, and therefore, many pedagogical attempts are made to bridge the gap between school and real-life, providing practical means for students to comprehend the subject. However, it has shown that this is not a trivial task, and a more expansive set of works are required in closing the expectation and the reality.

To tackle the fundamental issue in human resources, K-12 education should encourage more diverse intellectuals from various industrial and academic backgrounds, particularly in junior and senior years of high school, where students should be guided toward their future path, actuated

to discover a range of subjects from multiple angles through practical means. Notably, even though the high school courses are divided with clear boundaries and attributes, interdisciplinarity should be encouraged and promoted for connecting the discrete knowledge chains into a network, empowering students to develop an in-depth, comprehensive, connected, and practical understanding of the concept and the subject.

This is especially essential for more abstract subjects such as mathematics and sciences. Those subjects are not necessarily intuitive and, in many cases, hard to comprehend. Although these subjects are theoretically rigorous and abstract, they empower many real-life applications in economics, engineering, and manufacturing. Therefore, connecting theory to practice becomes essential for students to like, make sense of, and utilize the concepts in solving problems, concrete or abstract. Consequently, instructors can encourage more talented individuals, especially racial minorities and female students, to pursue further studies in the related areas.

Why It Matters: An Educational Analysis through Successful Intelligence Theory

Before the multiple intelligence theory was developed, several cognitive psychologists, such as Jean Piaget, believed in a singular *g* factor to categorize human intellectual capabilities, viewing it as a unified, indivisible, singular general ability (Piaget, 1952; Piaget, 1970). On the other hand, studies found that human performance is vastly different when they approach different tasks (Lilienfeld et al., 2018). Leading scholars, such as Howard Gardner, captured this phenomenon and proposed another viewpoint in analyzing the essence of the same notion, arguing that a singular empirical function cannot capture all human cognitive capacities, which is later became known as the multiple intelligence theory (Gardner, 1975; Gardner, 1979; Gardner, 1982).

Multiple intelligence theory refuses the notion of treating human intelligence and proposes that there are methods that can differentiate intelligence into branches that categorize certain aspects of human ability (Gardner, 1983). For example, Howard Gardner suggests an eight-branches framework under the notion of multiple intelligence theory, categorizing human intelligence into Musical-rhythmic and harmonic, visual-spatial, linguistic-verbal, logical-mathematical, bodily-kinesthetic, interpersonal, intrapersonal, and naturalistic abilities (Lilinfeld et al., 2018). Following the multiple intelligence theory frameworks, Robert Sternberg proposed a novel theory called the triarchic theory of intelligence, which catalogs human intelligence into three parts.

The triarchic model of intelligence divides human intelligence into analytical, practical, and creative intelligences. Analytical intelligence refers to the abilities for one to reason, which is the abilities for one to excel in standardized tests and traditional intelligence quotient (IQ) tests (Hertzog, 2018). Practical intelligence is the ability of one to solve real-world problems, especially the ones in relation to human interaction. It is the ability for one to practice, implement, and execute (Sternberg, 2018). Creative intelligence is the ability of one "to create, invent, design, imagine, discover, explore and innovate" (Sternberg, 2018; Sternberg, 2005).

Sternberg believes the traditional IQ test fails to capture the essential skills that one needs to become successful and stresses the importance of the role practical and creative intelligence play

in one's academic and work performance (Sternberg, 1997; Grigorenko and Sternberg, 2016). The deeper reason is its failure to recognize the diverse nature of what intelligence is further than a unitary factor of consideration. The IQ tests also fail to examine skills in practical and creative domains, which is arguably more important than analytical skills, which is what those tests are concentrating on.

Sternberg later supplemented his theory of triarchic intelligence by considering the humanenvironmental factors and expanding it into what is known as the successful intelligence theory. In addition to the triarchic theory, the successful theory emphasizes how one's ability in adapting, modifying, and selecting the external environment can facilitate their success in the long run. The theory formalizes the three stages of environmental considerations: from adapting to the surroundings, making limited modifications, to selecting the optimal environment to work in (Sternberg, 1999; Sternberg, 2016; Sternberg, 2018).

Putting the abovementioned phenomenon into the perspective of multiple intelligence theory, particularly Sternberg's triarchic theory of intelligence, the syllabi focus primarily on analytical skills and content-based instruction is lack of practical and creative exposure, which are the essential skills and determining factors of one's success. By utilizing the background of instructors with academic or industrial experiences, teachers are able to provide more concrete examples with practical meanings that enable students to internalize the knowledge introduced in the classes into a practical setting and intrigue students' curiosity and interests in the related subject. On top of the skills, these experiences can also assist students in practicing environmental skills, including how to adapt themselves in applying the knowledge they have to diverse practical and working settings, how to modify their modalities to fit and maximize their performance throughout the work, and how to select the best environment that they can immerse in.

Facilitating Instructors and Students and Promoting Equitable Educational Access

Admittedly, talents from the industry do not necessarily have experience teaching in schools or working with students, particularly at the K-12 level, and therefore is, lack theoretical exposure to the related notions and ideas in education, which is usually introduced in the programs toward an education degree, teaching qualification training programs, and practicums in higher educational institutes or educational organizations. This is a realistic concern and one of the primary justifications for the existing policies and regulations.

However, considering the expansive access to diverse educational content in various settings, including in-person workshops and online seminars, there are many approaches in which the talents could be educationally and psychologically prepared for the new occupation by introducing programs to facilitate teachers to master pedagogy, gain familiarity to the curriculum, practice design thinking, envisioning potential issues in education. Such programs include teaching preparation training, professional development workshop, and other supporting programs to best facilitate the success of the teachers and, therefore, the students. Specifically, professional development programs empowered by higher educational institutes are usually great sources in expanding the academic inventory of instructional theory and connecting to real-time practical

teaching scenarios. In addition, teachers can sign up for the courses and workshops that fit their personal experience the most, such as online and hybrid learning programs, educational technologies, instructional designs, and equity in education. Finally, it is also a good way for instructors to connect with like-minded fellows who may face similar issues in instructions.

The expansion in teaching qualifications by welcoming professionals with industry experience and academic experience without necessarily holding a degree in education or teaching certification is an excellent recommendation to encourage more talented individuals to enter classrooms, share their knowledge and skills with their students, and inspire the younger generations. Embracing the new members in the education team promotes more diverse perspectives in presenting the materials interactively and practically, encouraging meaningful and authentic learning, particularly in high school education. Inspiring students with real-world challenges under the project-based framework with edge-cutting problems in the industry correlates with the teaching materials could nurture all three aspects of intelligence according to Robert Sternberg's intelligence theory. This paper will discuss the educational and social implications of such change in conjunction with Sternberg's successful intelligence theory (Sternberg, 1999). This paper will analyze the significance and necessity of adopting such transformation in the globalized world. This paper will dissect the benefits and apply such theory in supporting the education of low socioeconomic communities and underrepresented communities. Finally, this paper will discuss why the all-embracing approach is necessary and suitable for further increasing the compatibility and accessibility of the redefined teaching gualification.

Conclusion

Echoing the Sustainable Development Goals 4.c, focusing on providing equitable educational access through supplying qualified teachers in a sustainable way, this paper recognizes the significance of current issues in teacher attrition and challenges for schools, particularly public schools in underprivileged regions and communities to recruit adequate qualified teachers and sustaining their teacher resources. We analyzed a few essential reasons for the formation of such a phenomenon and proposed an extended definition of teaching qualification. The reconstruction of teaching qualifications not only provides schools more autonomy in designing a more suitable curriculum for their unique student bodies but offers an inclusive framework for viewing what the qualification means. Following the augmented version of certification, institutes and instructors will encourage greater exposure to a bigger picture than what is constrained by the syllabi and connect the real-world problems in the instructional materials.

This paper provides a theoretical framework for the reconstruction and diversification of teaching qualifications with justifications from the viewpoint of multiple intelligence theory, students' motivation, and online and hybrid learning environments. Under the framework of Sternberg's successful theory of intelligence, such modification will adjust the focus of instruction more toward the practical and creative side of the spectrum, which is the determining factor of one's success in academic and post-academic worlds. This will also cultivate students' capabilities in adapting, modifying, and selecting the external environment, which is an essential skill and can support students' success in post-secondary education.

Future works on horizontal comparison with quasi-experimental designs can be effective in quantifying the significance of the proposal, and case studies concerning schools that adopt the modified interpretation of qualification, concentrating more on the qualities of educators themselves, can be developed to qualitatively strengthen the scheme in defining the effects in a more narrative manner.

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Racial Diversity - A Secret of High-Performing School Districts Across the United States

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Abstract

The United Nations' 2030 Agenda for Sustainable Development clearly states that the aim of the Sustainable Development Goal 4 is to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. In the United States, one long-standing challenge for creating inclusive and equitable educational opportunities in public schools is the deep skepticism toward racial diversity. Although many studies tackle this issue from a socioeconomic perspective, our study aims to uncover the academic benefits of racial diversity to all students. Extracting data from the Stanford Education Data Archive (SEDA), which includes longitudinal data of state testing scores over a ten-year span, we conducted descriptive and independentsamples t-tests to measure the differences in racial diversity between high- and low-performing school districts. The quantitative data analysis of 300 U.S. school districts showed that at any given socioeconomic level: high, low, or national-average, there is a significant difference in racial diversity between high- and low-performing school districts. High-performing districts at all three socioeconomic levels are more racially diverse compared to low-performing districts. This reveals that contrary to the stereotype that more students of color mean lower academic performance, racial diversity of a student body translates to higher academic performance and standardized test scores.

Keywords: quality education, racial segregation, school choice, academic performance, socioeconomic status, sustainable development goals

Introduction

In 2015, all UN Member States adopted the 17 Sustainable Development Goals and pledged full support to the attainment of the 2030 Agenda for Sustainable Development. In the 2016 Global Education Monitoring (GEM) Report, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) explained explicitly the role of education to sustainable development:

The SDGs, targets, and means of implementation are thought of as universal, indivisible, and interlinked. Each of the 17 goals has a set of targets. In each set, at least one target involves learning, training, educating or at the very least raising awareness of core sustainable development issues. Education has long been recognized as a critical factor in addressing environmental and sustainability issues and ensuring human well-being. (p. 9)

While quality education is critical to ensuring the attainment of the 2030 Agenda for Sustainable Development, nations, governments, institutions, and individual stakeholders have different opinions on what quality education should look like. Gough (2018) pointed out that in order to achieve Sustainable Development, global citizenship education – Target 4.7 of SDG 4 – must be given high priority. As stated in the 2016 GEM Report, education must teach people to think collectively and not individually: we have to work together for the planet. In the United States, however, one long-standing challenge in promoting global citizenship and creating inclusive and equitable educational opportunities in public schools is the deep skepticism toward racial diversity (Pine & Hilliard, 1990). Because school districts in more affluent communities tend to achieve higher test scores, they are often perceived as "high-quality" school districts. It is also evident that affluent communities consist of higher percentages of White population. The combination of the two factors led to a stagnant stereotype: the Whiter the school districts, the better they are. Consequently, school districts of less-White communities, and therefore consist of higher percentages of students of color, are seen as "bad" school districts.

In this study, we aim to tackle the skepticism toward school racial diversity by providing insights into the relationship between racial composition and students' academic performance in U.S. public school districts. To ensure that this study is focused on the relationship between racial diversity and academic performance and to avoid the influence of socioeconomic factors, we aim to draw comparisons between school districts that are at the same socioeconomic levels. In doing so, we ask the following research question:

To what extent does racial diversity or the lack of it account for the substantial differences in students' academic performance between school districts that are at the same socioeconomic level?

Literature Review

Racial Diversity in Public Schools

What is it like Today?

School racial diversity has been the center of stakeholders' attention for generations. Following the Civil Rights movement in the 1950s to 1960s, the most significant declines in school racial segregation were observed in the late 1960s and early 1970s (Reardon & Owens, 2014). After the rolling back of desegregation court orders in the 1990s, Orfield et al. (2012) found that the levels of school racial segregation deepened. Despite much argument about the cause, researchers agree that U.S. public schools are still highly racially and economically segregated today (Reardon et al., 2021a). School Choice programs, including magnet and charter schools, had little effect on racial diversity, and in some cases, increased racial segregation (Frankenberg & Lee, 2003; Arcia, 2006; Blatt & Votruba-Drzal, 2021; Wang & Herman, 2017, Chapter 11, p. 58).

Parents' Inner Conflict

After examining a number of empirical studies on the demographic characteristics of students and families who actively engage in school choice, Lacireno-Paquet (2008) concluded that parents' primary stated motivation in selecting schools is perceived academic quality; the primary influence in terms of documented behavior, however, is peer composition in terms of race and class. White parents say that they want their children to attend racially diverse schools, but when it's time to choose, they choose schools that are disproportionately White and higher income (Roda & Wells, 2012). White parents tend to avoid schools with high minority concentrations (Lacireno-Paquet, 2008). Billingham & Hunt (2016) also found in their experimental study that the proportion of Black students in a hypothetical school has a consistent and significant inverse association with the likelihood of White parents enrolling their children in that school. These higher levels of stereotype bias further inhibit school enrollment, particularly in schools with higher proportions of Black students (Billingham & Hunt, 2016).

Racial Diversity vs. Academic Outcomes

A Holistic Approach

A large body of literature discusses the need for and the significance of closing the achievement gap or test-score gap between racial groups and socioeconomic levels; for example, Orfield et al. (2012), Debs (2016), Matheny et al. (2021), Reardon et al. (2021), and many more. Among the efforts, three research threads were found: (1) observation of the widening or stagnating achievement gap and the causes, (2) the extent to which the achievement gap is harmful to underrepresented and disadvantaged students, families, and communities, (3) effective ways to close the achievement gap. All three threads address the issue from a holistic, or closing-the-gap viewpoint, i.e., how education or schooling as a whole can be improved.

A Survival Mindset

School choice programs are created to give parents more options for their children's schooling. While research focuses on how to improve education as a whole, parents simply want the best for their own children. Roda & Wells (2013) found that many upper-middle-class parents are bothered by the racial and socioeconomic segregation within and among schools, but they are simultaneously anxious and concerned that their children win the "race to the top" of a highly competitive and stratified system. The disconnection between the holistic research approach and individuals' survival mindset continues to drive parents away from real effort and contribution to racial diversity.

Benefits Instead of Morals

Instead of discussing the extent to which the exacerbated achievement gap is harmful to lowincome students and racial minorities, studies that present academic and social-emotional benefits of enrolling children in racially diverse schools are more likely to speak to parents. As the study of Schneider et al. (2021) indicates, White students in racially integrated schools appear to have more positive experiences than White students in less diverse schools, while achieving at the same rates or higher as measured by standardized tests. This type of work marks an important step in making a research-based case to White and higher-income families about the benefits of racial diversity. As history indicates, the moral imperative is not enough (Schneider et al., 2021).

In the current study, we join the effort to uncover the benefits of racial diversity to students' academic performance measured by standardized test scores.

Methods

This is an original study using quantitative data collected from the Stanford Education Data Archive and National Center for Education Statistics databases. We applied a multistage sampling design incorporating stratified and cluster sampling methods to compile three data sets and six data groups. Then, we employed descriptive and independent-samples *t*-tests to conduct quantitative data analysis.

Student Learning Rate and Socioeconomic Status Data

To investigate the between-district differences in students' academic performance, we relied on the data provided by Stanford Education Data Archive (SEDA). The SEDA longitudinal data consist of state testing scores from spring 2009 to spring 2018 in more than 13,000 public school districts across the United States (Fahle et al., 2021). Despite many challenges came with state testing data, SEDA was able to place the proficiency thresholds on the same scale, estimate the mean test scores in each school, district, and county from the raw data and the threshold estimates, scale the estimates so they are measured in terms of grade levels, and therefore create estimates of three parameters: average scores, student learning rates (SLR), and trends in average scores. Each of the parameters presents student performance in a unique way. We chose to use the SLR to measure school district academic performance, reasoning that it is the only parameter that reflects how much students improve from one year to the next. The SEDA database also provides the data of the average families' socioeconomic status (SES) of school districts in the United States. SES is a broad measure calculated using income, educational attainment, and employment data of all families living in the community that is served by a school district.

School District Racial Profiles

School district demographics data were gathered from the database of the National Center for Education Statistics (NCES). The NCES is part of the Institute of Education Sciences. The NCES database provides data on school district characteristics via the Education Demographic and Geographic Estimates (EDGE) program. The EDGE program uses the U.S. Census Bureau's American Community Survey, along with spatial data collected by NCES and the Census Bureau, to create indicators of demographic, social, and economic conditions.

Of the abundance approaches to the measurement of racial diversity, we chose the simplistic majority-minority approach (Zhang, 2021). According to the U.S. Census Bureau's 2021 report, 60.1% of the U.S. population are White – majority, while Black, Hispanic, Asian, Native American, and others together make up less than 40% of the U.S. population – minority. In this study, we measured school districts' racial diversity using the percentages of White population. Based on the simplistic majority-minority approach, a higher percentage of majority (White) population means that the district's racial diversity is low, and a higher percentage of minority population means that district is measured higher in racial diversity.

Sampling & Data Analysis

Based on the SES values provided by SEDA, we first divided the 13,000 U.S. public school districts into three socioeconomic levels: high-SES, low-SES, and national-average-SES. Then, we compiled three data sets of a total of 600 school districts, 200 districts from each SES category. The complete data of three data sets were ranked separately by SLR. In each data set, a high-SLR group and a low-SLR group were generated. Each group consists of 50 districts (Table 1).



Then, we conducted descriptive and independent-samples *t*-tests to examine the differences in racial diversity between high- and low-performing groups at each SES level. The descriptive statistics consisted of the mean and standard deviation of percentages of White population in high- and low-performing groups at three SES levels.

Results

Data Set L

Data Set L consists of 100 low-SES communities. These are the poorest school districts in the United States with a median household annual income of \$30,625. Economically, there is little to no difference between the two groups in this data set. However, the 50 districts of Group A

achieved a 12% higher academic growth per year compared to the national average while the academic growth of Group B is 32% lower compared to the national average.

Independent-samples *t*-tests were conducted to assess statistical difference in percentages of White population between high- and low-performing groups. In Data Set L, Group A had a lower percentage of White population (M = 0.17, SD = 0.22) than Group B (M = 0.32, SD = 0.24). A statistically significant difference in racial diversity between Group A and Group B was found (p < .05).

Data Set M

Data Set M consists of 100 average-SES communities. These are average U.S. communities with a median household annual income of \$53,008. Economically, there is little to no difference between the two groups in this data set. However, the 50 districts of Group C achieved a 13% higher academic growth per year compared to the national average while the academic growth of Group D is 15% lower compared to the national average.

Independent-samples *t*-tests were conducted to assess statistical difference in percentages of White population between high- and low-performing groups. In Data Set M, Group C had a lower percentage of White population (M = 0.76, SD = 0.27) than Group D (M = 0.84, SD = 0.16). A statistically significant difference in racial diversity between Group C and Group D was found (p < .05).

Data Set H

Data Set H consists of 100 high-SES communities. These are the richest school districts in the United States with a median household annual income of \$123,387. Economically, there is little to no difference between the two groups in this data set. However, the 50 districts of Group E achieved a 28% higher academic growth per year compared to the national average while the academic growth of Group F is 3% lower compared to the national average.

Independent-samples *t*-tests were conducted to assess statistical difference in percentages of White population between high- and low-performing groups. In Data Set H, Group E had a lower percentage of White population (M = 0.75, SD = 0.21) than Group F (M = 0.83, SD = 0.12). A statistically significant difference in racial diversity between Group E and Group F was found (p < .05).

Table 2 below presents the *t*-tests results of all three independent data sets.

Table 2

	,	,				
	Percentage of White Population					
	High-Performing Group		Low-Performing Group			
Dataset	Μ	SD	Μ	SD	df	t
L - Low SES	0.17	0.22	0.32	0.24	96.268	-3.269
M - Average SES	0.76	0.27	0.84	0.16	80.847	-1.946
H - High SES	0.75	0.21	0.83	0.12	77.122	-2.383

T test Statistics for Data Sets L, M, H

**p* < .05

Discussion

Racial Diversity and Quality Education

In the beginning of the study, we asked the research question: To what extent does racial diversity or the lack of it account for the substantial differences in students' academic performance between school districts that are at the same socioeconomic level? The results of our descriptive independent samples *t*-tests found statistically significant differences (p < .05) in racial diversity between high- and low-performing groups at all three SES levels: high-, low-, and average-SES. These results show that high-performing groups are consistently associated with a more diverse population. The statistical significance and consistency across SES levels indicate that (1) racial diversity accounts for the substantial differences in students' academic performance between school districts that are at the same socioeconomic level, and (2) school district racial diversity has a positive and significant impact on the learning outcomes of all students.

The existing body of literature on the academic benefits of racial diversity measured by standardized test scores is rather small and the findings are mixed. For example, McNalley (2005) hypothesized that White, middle-class children would do as well academically in racially mixed schools as in all-White schools. Using elementary school children's standardized test scores in reading and math, the study found no association between White, middle class children's test scores and the percent minority students in their schools. Methodologically, these studies often employed regression analysis to determine if racial factors and students' test scores are associated. Regression models are powerful statistical tools, but when used to find associations between racial factors and test scores, controlling other variables such as teaching practices, school culture, family socioeconomic status, and students' social-emotional and cognitive development can be very challenging, if not impossible. Our study employed *t*-test analysis to determine if there are statistically significant differences in racial diversity between high- and low-performing school districts. This variation in research design offers a possible explanation for the differences between our results and those of previous studies. Besides methodological reasons, historical factors could offer additional insights and explanations. Studies in the 1990s and early

2000s largely aimed at providing research-based evidence to change White, middle class parents' negative view on students of color. Instead of presenting the benefits of racial diversity, these studies strived to prove that racial diversity was harmless. Despite this limitation, these studies advanced the conversation about racial diversity in schools and helped reduce the stigma attached to students of color. Because of these studies, today's researchers are able to ask bolder research questions and showcase a plethora of benefits of racial diversity.

Horizontal and Vertical Comparisons of School District SLR

Student Learning Rate or SLR is a parameter provided by Stanford Education Data Archive. It is calculated by comparing students' average scores in one grade and year to those in the next grade and year. In other words, this parameter keeps track of grade-to-grade improvements in performance within each student cohort. The uniqueness of the parameter makes it a more accurate indicator of the education quality of schools and districts (Stanford Education Data Archive, 2021).

Figure 1 below presents the Student Learning Rates (SLR) between high- and low-performing groups at three SES levels: low-SES (Data Set L), average-SES (Data Set M), and high-SES (Data Set H).



Figure 1

The data points, as shown in Figure 1, present a great amount of information that was previously hidden. First, a horizontal examination provides information on SES and its effects. Observing the SLR of three low-performing groups (Figure 1, red data points), we can see that the average SLR of low-SES districts is -32% while the number of high-SES districts is -3%. Similarly, a comparison of the three high-performing groups (Figure 1, blue data points) shows that the high-SES districts' average SLR is 28% while the national-average-SES districts' average SLR is 13%, and the low-SES districts' average SLR is 12%. This visual presentation shows how the stratified economic

system advances the wealthy and deserts the needy, and unfortunately, the same effects are found in the education system. Although socioeconomic status is not the focus of our study, it is worth mentioning that our results confirm the findings of previous studies on SES and its great effects on students' learning.

A vertical examination reveals that although school districts within each given socioeconomic level had similar amounts of resources and faced similar challenges, the three high-performing groups (50 districts in each group) provided far greater learning opportunities to their students than the three low-performing groups (50 districts in each group) did. For example, in Data Set L, the students in the 50 high-performing school districts had a learning rate that is 12% above the national average, while those in the 50 low-performing school districts had a learning rate that is 32% below the national average SLR. Because of the scope of the current descriptive study, we are unable to investigate further into the causality of what was presented through the vertical examination. However, we strongly encourage future researchers to conduct causal studies on this interesting, yet often overlooked phenomenon.

Conclusion

The 2016 GEM report by UNESCO recognized that the right kind of education can reduce discrimination, crime, and help build stronger communities. Specifically, Target 4.7 of SDG 4 calls for global citizenship education, which can help learners to attain an individual, national, and global identity so they will be able to participate actively in solving international problems such as opposition, war, global poverty, and environmental challenges (Farahani, 2014). Education has the potential to transform the planet, but first we must transform the education system (UNESCO, 2016). In the United States, transforming the education system means promoting school racial diversity and amplifying the value of collective thinking and global citizenship - the very focus of Target 4.7 of SDG 4. School choice programs, which were created to provide equitable educational opportunities to all children, have been around in the United States for more than a half century. Unfortunately, so has choice-based school racial segregation, even when a growing number of parents say that they want their children to attend racially diverse schools (Roda & Wells, 2013). Besides legislative shortcomings, the lack of guantifiable and replicable evidence for the benefits of school racial diversity also plays a role. Utilizing quantitative data extracted from SEDA and NCES databases, our study found that high-performing school districts are consistently associated with a more diverse population, and this association is strong across all socioeconomic levels. These findings suggest that when choosing schools for their children, parents should put aside their own preference for race, and seek schools and districts that are more racially diverse. As more and more studies indicate, school racial diversity offers great benefits to children's learning and development. Meanwhile, our findings suggest that all stakeholders - students, parents, educators, researchers, and policymakers - should acknowledge that racial diversity is not charity. No one race is helping another or losing their advantage in achieving racial diversity. All children need a racially diverse learning environment to succeed.

Highlighted by the research aim, an area of significance of our study is that it is part of the effort to shift the conversation around racial diversity. The COVID-19 pandemic exposed the deep division in the society around almost all issues, extending to social, economic, environmental dimensions, and beyond. Arguments around racial diversity often became about who the beneficiary should be, implying that only some can benefit from the advancement of racial diversity. Aimed at investigating the extent to which racial diversity is beneficial to all students, we were able to join forces in promoting unity through our research. Another area of significance of the study is that our research design minimized the influence of socioeconomic status on the analyses of the relationship between racial diversity and student learning outcome. Researchers have long recognized that racial and socioeconomic factors are closely intertwined, and it is difficult to separate the two when needed (Longstreth, 1978; Callenbach et.al., 1981; Clayton, 2009). LaVeist (2005) stated that the problem of disentangling race and socioeconomic status is as much conceptual as it is methodological. By designing our study to investigate school districts within individual socioeconomic levels, we were able to collect focused data and produce more cogent findings. We hope our research design helps to shine a light on this challenge, and we hope future researchers continue to explore effective methods and chart various paths for learning the benefits of racial diversity.

There are some limitations of our study. Despite that SEDA – the database that made comparing longitudinal student test score data at a national level and across socioeconomic spectrum possible – consists of data of 13,000 U.S. school districts, we were only able to study 300 school districts. Also, the simplistic majority-minority method that we employed meant that individual groups of racial minorities, such as Black, Hispanic, Asian, Native American, and others, did not have individual representations in our findings. Furthermore, the scope of our research is limited to academic benefits measured by standardized test scores. Therefore, we suggest that future researchers conduct studies on school racial diversity with larger samples, utilize methods to the measurement of racial diversity that allow individual representations for minority groups, and investigate benefits beyond standardized test scores.

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Perspectives on Integrating the Local Context for Environmental Literacy: An Exploratory Study with Middle-School Teachers in India

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Abstract

Environmental Education (EE) needs to stay pertinent to the needs of the community amidst the rapidly changing socio-technological landscape. There are several barriers to applying the theoretical concepts of EE into real life situations, and negotiating such complexities to support environmental literacy remains a challenge for school teachers. This study aims to explore teachers' views and challenges towards contextualization of the curricular concepts to link theory with practice, and how their motivations to address this gap affect their approaches towards contextualizing environmental topics for the students. The methodology includes the analysis of EE content in the national curriculum textbooks in India and corroborating the resultant findings through interviewing teachers (n=10) from middle-school grades in semi-urban government schools of Rajasthan, India. The discussion reflects upon the issues within current practices of contextualisation of environmental topics and the connections which get marginalized in the attempts to bridge the theory-practice gap.

Keywords: Environmental education, India, teacher perception, local context, learner engagement, theory-practice gap

Introduction

There is growing acknowledgement towards the role of education in addressing contemporary challenges. Efforts for mobilizing educational resources for a sustainable future have been internationally encouraged by the UN Decade of Education for Sustainable Development (ESD) (UNESCO, 2005a). The current study corresponds with the UN Sustainable Development Goal 4 (SDG 4) of quality education, specifically Target 4.7 Education for Sustainable Development and Global Citizenship. Quality education can empower communities to achieve sustainable lifestyles through awareness and conscious transformation of knowledge into action. Environmental Education (EE) pedagogy forms a crucial part of ESD. EE encompasses integrated pedagogical approaches for, about and through the environment. Barriers towards achieving sustainable living practices, equitable access to natural resources, climate change awareness and allied issues are increasingly discussed as part of school EE curricula. Successful teaching-learning opportunities within EE rely on strategies for contextualisation of the curricula.

Environmental Education in Formal Curriculum

Environmental Education for Sustainability (EES) is "a learning process that increases people's knowledge and awareness about the environment and its associated challenges, develops the necessary skills and expertise to address the challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action" (Declaration of the Tbilisi Intergovernmental Conference on Environmental Education, 1978). Environmental Education works towards building environmental literacy. Globally several steps have been taken to improve EES teaching-learning resources, materials and practices. Efforts have been made to improve EE through inquiry experiences and skill development (Steele et al., 2016). Yet there remains a gap between students' environmental beliefs and their willingness to take pro-environmental action (Kollmuss and Agyeman, 2002).

In India, following the EES goals, one of the central concerns of the National Curriculum Framework (NCF) 2005 is to contextualise the curriculum to the learners' world, through blurring the boundaries between the school and its natural and social environment (NCERT, 2005). In the middle-grade school curriculum, EE is incorporated through an infusion approach which means that EE topics are blended into the science and social-science subjects.

Contextualizing the Curriculum

Context based approaches are processes and methods which help students to make connections between curricular concepts and real-world applications (Yamauchi, 2003). When the students engage with the larger debates along with the facts, they are able to transfer their learning from one context to another more effectively. Contextualized learning is important for environmental knowledge comprehension. When teachers relate textbook concepts to the local environment and students' personal experiences, it enhances curricular knowledge acquisition (Taylor and Mulhall, 2001). Contextual curriculum enhances community focused, learner focused and knowledge focused learning; incorporating local knowledge, language, and skills. While the multidisciplinary nature of EE promotes examination of contextual information (Song, 2012), there is limited research into analyzing the features of EE curricula from this perspective.

Teacher Perception Studies Regarding Contextualisation for EE

Previous studies have investigated teacher perceptions and practices of concepts such as issues within Education for Sustainable Development (ESD) (Anyolo et al., 2018), socio-scientific learning and environmental citizenship (Georgiou, 2021), environmental topics in science education (Ko and Lee, 2003) and so on. In India, there have been studies analysing environmental philosophies underlying teacher practices and narratives (Haydock and Srivastava, 2017); environmental awareness of middle-school teachers (Singh, 2012); among others. Although teachers' role and knowledge in facilitating environmental literacy among students is considered crucial, scholarly research on teacher perceptions and practices regarding contextualisation of the curricular content remain underexplored in India.

Rationale for the Study

We situate the current study with teachers in semi-urban government schools of Rajasthan, northwestern India. Land degradation, deforestation, water scarcity and depletion of common resources reflect the range of environmental issues prevalent in Rajasthan (Gagné, 2013). While several campaigns to promote environmental conservation have been active in the region, very few studies attempt systematic analysis into concerns around environmental education in the schools. Previous research with school and university students in Rajasthan has highlighted students' inability to comprehend the socio-ecological challenges associated with access to water (Chauhan, 2003), and lack of knowledge of and involvement in waste management practices (Arora and Agarwal, 2011). Such studies indicate the need for investigating the EE pedagogy practices present within the school curricula. Teachers' active engagement with curricular transformation has been acknowledged by researchers as an important catalyst in enabling students to connect curricular knowledge with life outside school (Batra, 2005).

Through our study, we aim to analyse the curricular content for the opportunities it provides with respect to contextualisation, as well teacher perceptions of the socio-cultural, political, economic, and curricular contexts within which learning takes place. We present a detailed analysis of the textbook content from science textbooks of Class 6 (NCERT 2018, p. 155-156) and 7 (NCERT 2018, p. 220-230) published by the National Council of Educational Research and Training (NCERT), along with findings based on teachers' interviews in the Discussion section of this paper. In order to understand how the curricular content gets translated into practice, we propose the following questions to understand teacher perspectives on contextualizing the curriculum for environmental literacy in middle-school:

What are teacher beliefs and perceived challenges towards contextualisation of environmental topics for enabling student learning and engagement?

How do teachers facilitate connections between curricular and contextual knowledge in environmental topics?

Research Methodology

The data collection for the study involved ten semi-structured telephonic interviews, which lasted approximately 40 minutes each. Purposive sampling was utilised in this study to ensure that participants would be able to provide the information required to answer the research questions. The teachers from the Science and Social Science background were selected as the environmental topics are infused in these subjects in middle-grade school curricula. The interviews were conducted primarily in the Hindi language. The nature of this qualitative study is exploratory and we do not intend to draw statistically significant conclusions from our findings.

The sample consisted of seven female and three male teachers, out of which six teachers were Science teachers and four were Social Science teachers. Their teaching experience ranged between 12 to 31 yrs. The participation in the study was completely voluntary and prior consent was taken for recording interviews. Participants were asked questions on their views, experiences and methods regarding contextualising environmental topics from the curricula. However, conversations were often woven around and guided by what the principal-researcher interpreted to be significant to the interviewees while they responded. This helped in revealing unintended categories and themes during data analysis.

Reflexive Thematic Analysis or RTA (Braun and Clarke, 2019) was considered most appropriate in the context of our theoretical underpinnings for the study. The method of RTA suggests that data is collected and analysed in a way that respects the participants' stories, while acknowledging researcher reflexivity when interpreting the data. Thematic Analysis involves finding repeated meanings across a data set, which is crucial to the interpretation of phenomena. The analysis is recursive and iterative, and the phases of analysis include: familiarisation with the data, generating initial codes, generating themes, reviewing potential themes, defining and naming themes and producing the report.

After each of the interviews was conducted, the researchers created a transcript of the interview. The teachers' own accounts of their opinions and experiences have been expressed by the researchers as truly as possible, while also embracing their own interpretations as researchers. Themes from the data were produced by organizing codes around a central organizing concept interpreted from the data.

The paradigmatic framework of interpretivism and constructivism (Schwandt, 1994) guided our study. These frameworks allowed us to incorporate a combination of both deductive and inductive analysis approaches. A primarily inductive approach was used in our study, as we conducted open coding of the data, giving importance to data-based meanings. However, deductive analysis was used to a certain extent to make sure that the data-based meanings and the themes we generate stay relevant to our research questions. While performing open-coding we gave equal importance to both semantic and latent level codes. We intended to code the semantic meaning communicated by the participants, and the latent meanings that we interpreted as researchers.

Findings

Four major themes were identified (Fig.1 Thematic map): school context; framing the concepts within activities; stepping beyond the classroom and; diversity of learner experiences and backgrounds. In the subsequent paragraphs, we detail each theme along with respective subthemes.



School Context

This theme relates to the factors seen as important by the teachers to frame the concepts in environmental education topics considering the place where teaching-learning occurs, and its relationship with the surrounding community.

Interactions with the School Landscape

Teachers' ideas of building connections between the students and their immediate surroundings seemed to be based on possibilities generated by the school infrastructure and landscape.

'There were only two dustbins in our school earlier. The children had gotten into the habit of dumping food wrappers and pencil shavings in between each other's chairs so that teachers would not notice. We teach them to remember to put trash into dustbins, but it is difficult to make students put it into practice. Recently our school received more dustbins.'

With reference to the textbook activity of inspecting drains in one's locality or neighbourhood, the teachers mentioned using the school premises as it is safer and the teachers could ensure that the students performed the task under the teachers' supervision. The teachers prepared an

extended exercise wherein the students learnt about the water supply system by connecting with the school personnel.

'We cannot ask the students to trace the drains in their area to look for contaminants. This task would require adult supervision. Instead, we ask them to observe how wastewater is generated in the school itself. We ask them to click photos or make drawings of the activities which result in wastewater.'

Teachers perceived gaps between the curricular objectives and the prevalent school culture.

'Our premises has huge trees of eucalyptus, bamboo and all sorts of ornamental plants. The school authority restricts children from walking in the garden. How will the child ever know the names and importance of indigenous plants?'

Explorations Beyond Formal Learning

Self-directed learning was acknowledged as important as one teacher narrated about how a student started making informative videos about local birds with his neighbour and posted them online. The teacher was 'very happy and encouraged other students to make similar videos in the school yard'. Instances of incidental learning and the role of non-academic activities for promoting it were appreciated by teachers. Academic pressures were seen as disrupting the scope for such opportunities though.

'There is a small break between the assembly time and the first class. During that time the students can either have some snacks, read the newspaper in the library, play in the grounds, or just take a short nap. But I have seen most students quite tense during this time, busy finishing their homework. How does one expect students to grow aware of their surroundings, and think besides the defined academic requirements?'

Teachers seemed to reflect upon the strengthening of teacher-student relationship through such experiences.

'It was lunchtime and the students were playing in the school ground, when they noticed an injured squirrel. They called me and we brought the squirrel to the classroom. Children learn through such incidents. We made a feeder and a shelter for the squirrel, all of us together!'

School-community Relationship

Teachers shared the need for involving parents of the students in the activities of the school. They felt that the role of parental support in the child's learning was important for the child to bring their learning into practice.

'Parents of the students should also be involved in the tree plantation events at the school. But usually, the children gather and then we click some pictures and that's it.'

The teachers highlighted the school agenda behind organizing environmental awareness campaigns, and suggested extending such activities for wider community participation.

'Hosting a cleanliness drive in the school is not enough. It should extend to the students' home and the neighbourhood. But we just did a small event when the inspectors came for evaluation.'

Framing the Concepts within Activities

Teachers' preferences and methods for conducting the activities for environmental learning and awareness are discussed under this theme.

Teaching-learning Conceptions Regarding EE Pedagogy

Teachers referred to socio-cultural practices related to sustainability and intergenerational sharing of knowledge in their descriptions of activities. Health and well-being were also perceived as a neglected aspect in the content of textbook activities.

'Our culture already teaches us to avoid wastage. I bring examples from our own culture and community practices. People in villages of Rajasthan keep a wide wok-like container below while taking a bath on a cot, so that all the dirty water gets collected in the container which can be later reused for other purposes. That is how our ancestors have taught us to conserve water in the desert.'

'The problem of sanitation is acute in many rural areas. They dump waste in the open. The students see this everyday around them, so I ask them to make detailed projects on this issue. Such activities need to be promoted, rather than just making posters.'

Sense of Ownership

Using found materials was considered as a typical activity in lessons on waste management. Teachers associated the 'best-out-of-waste' activity as a way to connect student learning with their home environment. When narrating instances of supporting student interest through handson activities for environmental action, upcycling was considered as a more 'convenient' activity as compared to activities which demand more effort and patience such as composting, planting seeds and segregating waste. The activity also brought instant results, which the teachers saw as important for developing a sense of ownership in the students.

'We always conduct the Christmas tree decorations session. It is convenient, as children bring waste material from their home and they feel a sense of achievement after making something new from trash.'

'We had a compost pit in the school once. But nobody takes care of it, nobody has the patience. The most loved activity is where students get creative like in best-out-of-waste. They enjoy owning the responsibility of collecting trash from their home and making something useful from it.' The craft activities were preferred as they were perceived as requiring minimal teacher involvement. It was assumed that the activity would increase the students' creative skills and their engagement in environmentally-responsible behaviour.

'Children can be left on their own with craft or art activities. I am able to complete my evaluations during that time. And the children develop good behaviour towards the environment by making new things out of old.'

Communicating Moral Values

Valuing nature was seen as an important step in exploring and documenting the past and relating it to the present. Teachers emphasised the role of developing the wisdom to distinguish between right and wrong and applying it to nurturing the human-environment relationship.

'I ask my students to find out about the *Khejri* trees and how they were protected by the local communities. Children need to realize and value the efforts put in by our ancestors in conserving them.'

'I think it is important to talk about values. Just yesterday I saw some children get into a fight on the bus to school. I cite these examples to my students in class, and make them prepare a do's and don'ts chart. Cutting trees and hitting people should be on the same don'ts list. Planting trees and helping people should be on the same do's list.'

Teachers spoke of instances wherein they became role models and wanted children to be inspired to see through the issue of social stratification, by engaging in work which was seen as inferior.

'When I come to the class, I clean the desk and dust the shelves. One day the cleaning staff came on duty and saw the students dusting the class furniture. This sparked a conversation between the students and the staff. Students spoke to the staff about their work, their life. Students need to understand that cleaning is not someone else's job, it is not lowly.'

Sharing Multiple Perspectives

Sharing various dimensions around popular places and events was considered relevant by the teachers in terms of exposing the lesser-known stories of environmental 'damage'.

'I show contrasting images of the Udaipur lakes, those in which the local organizations can be seen cleaning the lakes and then those in which the huge lavish events can be seen catering to thousands of tourists. I also ask students to bring such photos from newspapers and make videos of their surroundings.'

'When I teach concepts on pollution, I ask students to walk into the schoolyard and the lanes near our school and notice the types of pollution. The obvious answers they give are noise and smoke from cars. Then I remind them of Diwali, the festival time when firecrackers burst on the road. The discussion does not end there. I tell them about the condition of the workers who make those firecrackers. That is how students can link social aspects with ecological issues.'

There were instances where teachers used videos to include news of natural disasters such as tsunamis, floods, and droughts while explaining about the water cycle. Collecting news reports on the issues was a popular activity given to students, especially to bring out an emotional response from the students, mostly that of 'shock'.

'Rajasthan experiences severe water scarcity. These days we have rainfall at random intervals, which is all due to the environmental disturbance. I show students the weather statistics and the destruction of crops, so they feel the shock.'

'I recently captured photos of dead cows in our locality. The heaps of plastic waste in the garbage are the problem. The students made faces upon seeing the photos. But photos like these should be shown. I asked them to click pictures of plastic products in their homes, and count them.'

Stepping Beyond the Classroom

This theme corresponds with the teachers' views on including the outdoors and engaging with the community.

Indirect Inclusion of Environmental Issues

Teachers tried to find ways to bring students closer to thinking about environmental issues while playing or going for site visits.

'We took our students to visit a solar panel project because the government has been making efforts to motivate children into taking up sustainable agriculture as a career. Through this tour we explained to them about environmental issues prevalent in their community.'

'When students go out to play in the school grounds, I ask them to pick up the trash lying around. It becomes a kind of competition to see who picks the most trash! This way they enjoy and don't even realise that they have cleaned the ground. When they come back to class, I talk to them about the various types of waste present around us and its hazards.'

Purpose of Field Trips

The teachers acknowledge the value of field trips, but the purpose of such trips was not linked with academic goals.

'When we take students out on nature camps, we just want them to have a good time. We don't get them to do any activities or put them under stress. The camp is a mandatory activity, so we have to do it. We can include learning-activities, but then that is another task to plan for.'

The teachers preferred keeping the trips 'stress-free' for the students, and avoided putting in efforts to plan any activities to be included in such trips. Perceived barriers include time-crunch, excessive involvement with planning travel logistics and so on.

'Exploring the nearby zoo is a fun trip. It increases recall for children, they are able to recognise different species of animals, and observe them. They are happy as it is like a picnic for them. We have to put in our time to ensure the safety and transport arrangements. That itself is quite a lot.'

'Trips are good and are part of the syllabus, but we mostly take them to visit nearby forts only. We don't do discussions or any such thinking task, we just do sightseeing.'

Planning for Community Engagement

Teachers described arranging the community-engagement activities in the beginning of the lesson, irrespective of the activity's placement in the textbook chapter. They felt that it allowed students to explore prior knowledge through discussions with family members before diving into the textbook concepts.

'I tell my students to speak to their grandparents about how they lived without electricity. We then have a discussion in class the next day. All children may not have done the task, starting the lesson with such discussions can be helpful. This was an activity I thought of, based on another activity given in the textbook exercises at the end of the lesson.'

'I asked the students to collect packaging of products used by their family members, and discuss the types of materials used in the packaging. We did this exercise after watching a short film on waste. They can quickly relate the two together.'

Diverse Student Experiences and Backgrounds

This theme relates to teacher perceptions of how student backgrounds, attitude and experiences affect the way they understand environmental concepts and develop pro-environmental competencies.

Fragmented Narratives

The students' inability to relate the curricular knowledge with contextual knowledge was noticed by teachers, and the teachers felt that such situations led to misconceptions.

'A student asked me why people in his neighbourhood did not follow the habit of disposing garbage in the dustbin. I find it difficult to handle the differences between what needs to be taught and what the students actually notice in their surroundings.'

'I ask students to grow a vegetable in their vicinity and take care of it without using pesticides. Those students whose parents are farmers, see that pesticides are being used in the field. So, they get confused. How can they apply their learnings in real life then?'
Broad Range of Students

Students from various socio-economic backgrounds possess contrasting experiences and attitudes, which are perceived as affecting the students' ability to learn and understand ideas around sustainable living.

'Students come from different backgrounds. Some of their parents are farmers, so they are close to nature. They even bring vegetables from their farms and share with their friends. The students who reside in more semi-urban areas are not very close to nature spaces. Students learn a lot from each other's diverse experiences.'

'Students from urban areas are more relaxed about using water and electricity, and need to be told about resource conservation. But students from rural areas are very conscious of wastage. The difficulty is that the same examples may not be appealing to everyone.'

'Access to water is an issue in Rajasthan, especially in rural communities. Women walk long distances to fetch water. But these discussions are difficult for urban children to understand.'

Drawing from the Language of the Students

Teachers regard language barriers as a key issue while teaching the environmental topics. They regard the use of poems, role-play and stories to 'ease' the students into the scientific aspects of the content.

'There are local poems in the Marwari language with reference to water, rain and seasons which I collect and keep in the library. When I read it out to the students and ask them to recite it, and then begin with the textbook lesson... that way they become comfortable with the lesson.'

'Some students from rural communities do not understand some scientific terms in the textbook. So, they may not understand the concepts easily. In such cases, I have to ask them the local language terms, or draw pictures.'

'I often ask my students to go out into the school grounds and bring dry branches or leaves and make crowns out of them. Then they have to enact the tree and talk about its uses in any language they are comfortable in. This way it is easier for them to learn and express.'

Discussion

The themes in our findings reflect the approaches regarded as important by teachers to contextualize EE for students. These approaches correspond with the focus areas of place, student, pedagogical practice, attention to diversity and disciplinary content; as identified in previous research (Fernandes et al., 2012). Teacher's perceptions revealed that teachers view the process of contextualisation as having structural and affective aspects. As the bridge between

the curriculum and the students, teachers see themselves negotiating their ideas around EE pedagogy and the multiplicity resting within the narratives of the students' lived realities.

Place is believed to have strong cultural features, and curriculum design and teaching-learning methods need to take into account the daily routines, habits and social interactions that unfold in the school scenario (Kemp, 2006). The community's needs and the economic context are seen by teachers as essential while conceptualising the pedagogy for localisation. The meaning of local knowledge needs to be seen through a dynamic lens, to allow the inclusion of characteristics of the place.

The teacher responses prominently include the role of the school context, and activities that encourage beyond-classroom experiences in shaping the students' connections with their home, neighbourhood and city. While teachers' intent towards encouraging outdoor engagement is visible, their motivation to transform such opportunities into tools for contextualisation is lacking. Teacher's role in planning, implementing and reflection impacts the success of field trips in becoming effective educational tools (Behrendt and Franklin, 2014). But training and support are crucial to empower teachers to learn methods for conducting such trips and aligning the experiences to EE learning objectives.

The textbooks suggest certain out-of-classroom activities, but offer minimal guidance towards their implementation. For example, exploring the sewage route in one's locality. This activity and other similar ones are meant for students to understand wastewater management through physically exploring the localities. However, the textbook does not mention appropriate safety guidelines to consider during such tasks. The teachers while referring to this activity were found to be adapting it for the school campus instead of nearby localities. There is yet another textbook activity which prompts the students to interact with waste collectors or 'rag-picking' children and think of ways to help them 'read and write'. The activity is meant to promote socio-scientific inquiry among students. However, the lack of direction towards planning and facilitating direct experiences within outdoor spaces and social interactions with communities, may overshadow the opportunities for students and teachers to realise such an inquiry. Moreover, field trip goals are treated as detached from EE objectives, and such trips are perceived as an escape from the usual coursework and assignments.

While the textbook content attempts to make the environmental topics more accessible and interactive through the questions and illustrated characters, the depth of the message seems to get compromised, and communication of ideas remains didactic and oversimplified. The teachers too seemed to believe that EE is 'simple' to teach in comparison to 'heavier' science subjects. Consequently, the framing of environmental and sustainability issues becomes skewed, succumbing to a fragmented narrative. With reference to their motivation towards the need to contextualize the content, the teachers seem to have tautological answers such as 'the importance of the environment is significant to life' and 'we need to learn from the environment because it is everywhere and all-around us'. The teachers seem to be caught in the middle of having to adhere to the curricular content and wanting to discuss alternate examples and realities surrounding an environmental concept.

In order to develop equality within education processes, contextualised practices are seen as imperative. Research into contextualisation highlights the need to take care of student interest, nature, experience and background to support meaningful learning (Doyle, 2009). Opportunities for inclusion of diverse learner backgrounds could be created through context-aware teaching-learning methodologies (Kalbach and Forester, 2006). Still, teachers' responses reflect that they are not able to devote much time towards discussions on issues that stem from the contrasts of everyday lives of students living in the rural and urban areas. Previous research indicates that focusing on local history, identity and value systems can help in developing contextualised learning situations (Goodson and Deakin Crick, 2009). Teachers attempt to highlight local histories, but mostly tend to touch upon common examples devoid of intricacies, and quickly skip to global environmental-crisis examples.

Textbooks seem to contain minimum guidance towards planning of resources to conduct the activities, and this could prevent translation of knowledge into practice. For example, in the textbook, hands-on activities such as vermicomposting and paper recycling would require certain materials which may not be readily available. Also, the process of composting needs to be tracked across a month's time and requires the school premises availability and suitable conditions for conducting such an activity. Hence these tasks are not completely student-led and their execution might differ according to the facilitation and resources provided. We find that teachers also believe that composting may not be feasible in their schools, and the best-from-waste activity seems to be the preferred one instead. Use of words in the textbook such as 'chicken mesh' and 'gunny bag' may be obscure for learners, especially without the presence of any visual depiction. So, the application of the concept of compost would remain a challenge even if the concept is explained in great detail in the textbook. The teacher interviews also reflect the teachers' practices to make sure that language does not become a barrier for students' learning.

Teacher responses seem to indicate that their practice of contextualisation remains constrained within the didactic mould of instruction. Opportunities for incidental learning which means everyday learning that happens either incidentally or by seeking information individually (Marsick, 2016) may not always be supported in the formal school scenario. Reasons for this may include the hidden curriculum in the form of restrictions imposed by the school authorities and the design of school landscapes, as observed in the teacher interviews. Contrasting priorities of school authorities, teachers and curriculum developers are evident in these observations.

In spite of the efforts made by the curriculum developers and the teachers' attempts at contextualising EE, critical thinking around issues seems minimal. The value and significance ascribed to a concept may push other facets of an issue to the periphery, thus making it difficult for students to parse through the systemic linkages which connect the various elements of a complex phenomenon to the student's personal experiences. For example, activities such as best-from-waste are chosen by teachers because they are feasible and associated with bringing a sense of personal agency and empowerment to the students. These activities however do not get extended into meaningful teacher-student interactions to uncover deeper questions around the notion of waste or the difference between upcycling and recycling and so on. Similarly, news reports were referred to for generating a sense of 'shock', rather than careful dissection of the

underlying issue. Consequently, students may not express their ideas, experiences, opinions, misconceptions, and questions. In the absence of such opportunities, applying the knowledge in new contexts might become a challenge.

Limitations

The findings of the study are to be viewed amidst certain limitations. We may not know whether the teachers' comments reflect their actual classroom practice and circumstances as the data for this study was drawn from telephonic interviews only. Also, we are not aware how frequently certain pedagogical practices are used by the teachers and exactly what type of activity structure is being referred to by the teachers. Being an exploratory study, the sample size is limited. Class observation and in-person interactions could not be conducted owing to Covid-19 pandemic restrictions. The teachers' responses may also have been affected by the non-classroom location they might be present within while responding. Regardless, our study attempts to reveal the diversity of teacher perspectives pertaining to local context integration for environmental literacy, particularly in the Indian region of Rajasthan where such studies have been scarce.

Implications and Further Scope

Our analysis reveals the preferences, challenges and choices present in pedagogical practices of teachers and their relationship with the EE curriculum goals. These insights are relevant for curriculum developers and environmental education experts in understanding the deterrents and opportunities in realising the EE objectives. The current study guides us into thinking about questions such as, who may be defining the context for EE, what comprises the context and how might the framing of it evolve over time?

The findings from this study provide a base for exploring the design and delivery of EE modules. Further research can analyse how teachers contextualise for specific environmental sustainability issues. Empirical studies can be planned to understand the role of school culture and its impact on student's environmental interactions. Local issues and community values could be studied in relation to the curricular activities.

Conclusion

Current attempts to facilitate EE objectives present moments which enable connection of content knowledge to the students' real-world context, but there are lesser opportunities that allow students to apply the content knowledge to a new real-world setting. Thus, the process of contextualisation ceases to be iterative, and instead becomes static disparate interludes. The plurality of contexts presents a web of interconnected subsystems which are difficult to permeate through in absence of flexibility from established pedagogical frameworks. Consequently, the students' experiences wind down to linear explorations rather than flourishing into active attempts to apply their learnings to new imaginations.

In preparation to explore the full potential of EE, the curriculum material needs to allow students to immerse in the issues through critical questioning, develop solutions, support ideas and present their data while exploring the local context. To this end, the educators and curriculum designers must work towards planning and assessing the accessibility of the knowledge components and the activities. A major challenge lies in re-shaping the school curriculum in order for it to include not only the content but also the teaching practices and informal instruction; for the transmission of a holistic model of EE.

The SDG 4 supports the role of education in advancing knowledge, skills and attitudes necessary for learners to develop the ability to make informed decisions. To strengthen the contribution of education for accomplishing responsible citizenship in resolving local and global challenges, contextualised learning opportunities are vital. Contextualisation improves the relevance of education, thereby improving the quality of education. Hence, research on approaches for contextualizing formal EE curricula across students' home, community and school is required to systematically analyse efforts and monitor progress towards achievement of quality education for sustainable development.

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Culture and the Sustainable Development Goals: An Outlook of Future Opportunities

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Abstract

The purpose of this integrative literature review paper is to examine, from an angle of sustainability, how culture can contribute to the localization and achievement of SDGs. Specifically, this paper is to 1) reflect on the synergies between culture, ESD, and people-based Sustainable Development (SD), and 2) examine studies involving youths as the future potential for achieving the SDGs through culture. A varied range of literature was analysed to set up a method of inductive thinking, starting with specific examples and inferring towards generalizations. Drawn on studies from tangible and intangible heritages, the results identified two emerging thematic areas: 1) how culture presents future opportunities for achieving SD and provides a solid understanding on the synergies between culture and ESD, and 2) how culture has aided the progression of SD through youth engagement. The implication of the present study is to uncover strong connections between culture and SDGs and inherited reasons why culture matters for SDGs. More importantly, the paper highlights culture is not "good to consider" but must be taken into consideration as an intrinsic domain of human existence in all efforts to achieve SD.

Keywords: culture, cultural sustainability; Education for Sustainable Development; SDG 18; youth empowerment; people-based Sustainable Development

Introduction

This integrative literature review paper is to explore through a lens of sustainability how culture, in its different expressions, is an essential provider of future opportunities for the success of Sustainable Development (SD). The purpose of this paper is to illustrate the question "Why culture matters in SD" by analysing the vitality of culture in achieving SD based on the current scholarly dialogue on culture, youth, and Education for Sustainable Development (ESD).

The term "culture" can be understood as the collective practices of a specific group of people, their history, literature, arts, and other practices (Mahfoodh and Alhashmi, 2020). For Murdock (1932), individuals carry culture, and no individual is free of culture as everyone is raised in a cultural environment. Murdock (1932) further observes that culture is not innate. The continuity of culture depends on individuals of every generation acquiring the culture anew from the previous generations. Hence, particular elements of culture depend on intergenerational teaching and learning. Lamsal and Pokhrel (2021) state that humans and culture are mutually interdependent, for "man is a cultural animal" (Lamsal & Pokhrel, 2021). Levin and Mamlok (2021) see culture as "a human creation". It is inferable that all peoples are cultural beings because culture is intrinsic

to human existence, it is blended with, and permeates every human experience. Yet despite these insights, the Sustainable Development Goals (SDGs) have marginal mentions on culture or culture-related terms with only four targets containing such terms. The terms "culture" and "heritage" are entirely absent in the most recent text of *The Sustainable Development Goals Report 2021* (UN, 2021). In the literature on SDGs, culture is often referred to as a "driver", "enabler" or "social glue". However, various actors ascribe to culture a far stronger role than these terms. Culture's contribution to the realization of the SDGs has not been sufficiently acknowledged (Hosagrahar, 2017). There are calls for culture to be named as a fourth pillar (Ruigrok, 2009; Dessein et al., 2015) or dimension for SD (besides the currently named social, economic and environmental pillars), or referring to culture as "SDG 18" (Voices of Culture, 2021; Poole, 2018). The British Council talks of culture as "The Missing Pillar" of the UN 2030 Agenda for SD (The British Council, 2020).

Similarly, the movement of global cultural networks that produced the joint communique "The Future We Want includes Culture", released in 2015 by the Global Campaign for Culture "#culture2015goal", was revitalized as "#culture2030goal" (Culture 2030 Goal Campaign, 2019). Further efforts are being made to relate SDGs more intrinsically with domains of culture. An example is the introduction by the UNESCO of a framework of twenty-two thematic indicators referring to culture, as a voluntary complement to the existing 2030 Agenda indicators (Culture]2030 Indicators, 2020). The structured dialogue between representatives and organisations of the cultural sector and the European Union and the European Commission, Voices of Culture, is an additional case in point. These global voices evidently indicate the need to acknowledge the importance of incorporating the cultural sector more strongly into SD.

The aim of this paper is to review how culture matters for SDGs by exploring the opportunities offered by the synergies generated between culture and ESD and identifying how culture can empower next generations (i.e., youth) to achieve holistic SD. The scope of the integrative literature review includes scholarly and grey literature, and web searched documents mainly within the time frame 2015 – 2022, coinciding with the SDG era. This paper seeks to answer the following research question: What are the concrete opportunities that the synergies between culture, ESD, and youth offer in achieving SDGs? In terms of objectives, this paper proposes to 1) examine the synergies between culture and ESD, and 2) examine studies involving youths as the future potential for achieving the SDGs through culture.

In the following sections, it shall explain the methodology including the selection process and criteria of the integrative review. Findings are illustrated along with two thematic areas, namely culture and ESD, and culture and youth empowerment, providing reflections on the synergies between culture and ESD and future opportunities that these synergies hold towards achieving SD. Examples analysed in this paper include localizing SDGs efforts involving cultural domains as well as through youth engagement with tangible and intangible cultural heritage. The conclusion shall sum up the paper's synthesis, the limitations of the review, and further questions to explore.

Methodology

The present paper is an integrative literature review that aims at generating contemporary reflections on culture and SD. Torraco (2005) defines integrative literature review as "a form of research that reviews, critiques, and synthesizes representative literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated". Integrative literature reviews address emerging topics and provide holistic conceptualizations. Thus, preliminary conceptualizations are generated that offer new perspectives on the topic e.g., taxonomies and other conceptual classification of constructs (Torraco, 2005). For the present review, the focus will lie solely on the youth as bearer of future sustainability issues (Johnson et al., 2021). The analysis shall complete a critical reading and review of a selection of literature on the chosen subject with the purpose of synthesizing findings. The sources of the literature selection are scholarly journal articles of peer-reviewed scientific articles from the academic databases of Scopus and JSTOR. For more current information on culture and sustainability and to broaden the search, the scholarly literature was complemented primarily with grey literature and documents of international organisations, NGOs, and the online web data from projects such as Voices of Culture, reports from Culture 2030 Goal Campaign, and the online presence of university departments, research programmes or initiatives. This search was conducted online by web searches with the search engine Google.

The literature review, in its function of setting a framework for defining the significance of the study (Creswell, 2014), contains inclusion and exclusion criteria. To select the literature for analysis, some inclusion criteria were the presence of the keywords "culture", "sustainable" or "sustainability". In order to correlate present challenges of SDGs, their localization, and to provide an outlook into future opportunities, it is important to consider the present youth as representants of the future. As education is also closely related to youth and sustainability issues, literature concerning ESD was also considered. Therefore, as a second criterion for selection, the selected studies also include literature concerning "youth", and "Education for Sustainable Development" (henceforth: ESD). The exclusion criteria narrowed down the results by limiting the documents taken into consideration to the years 2015 to the present year of 2022, to coincide with the SDG era. As a result of the inclusion and exclusion exercise, the total number of literatures reviewed for the current study is 53. The collected literature provided a starting point for the method of inductive thinking, beginning with specific examples and inferring towards generalized explanations (Creswell, 2014). Following the funnel method as proposed by Hofstee (2006), the literature is arranged thematically.

Findings

Culture and Education for Sustainable Development

As stated earlier, the notion of culture in SDGs is marginal. Within the text of the SDGs: *Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development* (UNDESA, 2022), a search for the word "culture" yielded a total of four matches (see Table 1). It appeared twice in Target 4.7, once in Target 8.9, and once in Target 12.b

(see Table 1 for a detailed summary of results). A search for "heritage" yielded three matches, appearing all in SDG 11: once in Target 11.4, and twice in Indicator 11.4.1. The results show that culture is explicitly correlated to sustainable tourism in Targets 8.9 and 12.b, while Target 11.4 is mainly associated with tangible cultural heritage. Since the present paper excludes the economic dimension from its scope, the discussion shall focus on the implication of the search results for SDG 11 and SDG 4, leaving aside SDG 8 and SDG 12.

	Source: UNDESA (2022)		
Goal	Target	Indicator	
Goal 4. Ensure	4.7 By 2030, ensure that all learners	4.7.1 Extent to which (i) global	
inclusive and	acquire the knowledge and skills	citizenship education and (ii)	
equitable quality	needed to promote sustainable	education for sustainable	
education and	development, including, among others,	development are	
promote lifelong	through education for sustainable	mainstreamed in (a) national	
learning opportunities	development and sustainable	education policies; (b)	
for all.	lifestyles, human rights, gender	curricula; (c) teacher	
	equality, promotion of a <u>culture</u> of	education; and (d) student	
	peace and non-violence, global	assessment.	
	citizenship and appreciation of <u>cultural</u>		
	diversity and of culture's contribution to		
	sustainable development.		
Goal 8. Promote	8.9 By 2030, devise and implement	8.9.1 Tourism direct GDP as a	
sustained, inclusive	policies to promote sustainable tourism	proportion of total GDP and in	
and sustainable	that creates jobs and promotes local	growth rate.	
economic growth, full	culture and products.		
and productive			
employment and			
decent work for all.			
Goal 12. Ensure	12.b Develop and implement tools to	12.b.1 Implementation of	
sustainable	monitor sustainable development	standard accounting tools to	
consumption and	impacts for sustainable tourism that	monitor the economic and	
production patterns.	creates jobs and promotes local	environmental aspects of	
	culture and products.	tourism sustainability.	
Goal 11. Make cities	11.4 Strengthen efforts to protect and	11.4.1 Total per capita	
and human	safeguard the world's cultural and	expenditure on the	
settlements inclusive,	natural heritage.	preservation, protection and	
safe, resilient and		conservation of all cultural and	
sustainable.		natural heritage, by source of	
		funding (public, private), type	
		of heritage (cultural, natural)	
		and level of government	
		(national, regional, and	
		local/municipal).	

Table 1 SDG Text Containing "Culture" and "Heritage"

Possible direct ways of associating culture to SD would be linking culture with education, i.e., emphasizing cultural and artistic education, education for cultural diversity, and formal and informal heritage education. Heritage education correlates culture and education for achieving target 11.4 and presents a synergy that is perhaps not explicit as such within the official SDG text. Jagielska-Burduk et al. (2021) argue that protecting cultural heritage requires more than solely protection policies, administrative apparatuses, laws, and legal instruments. Citizens also play a vital role in cultural heritage management, and the development and success of cultural heritage protection is determined by the relationship citizens have with their cultural heritage. For the successful protection of cultural heritage, the authors consider as vital the inclusion of citizens in cultural heritage management, and, for added success, the cultural heritage education of citizens (Jagielska-Burduk et al., 2021). Fontal and Gómez-Redondo (2016) echo this thought in their affirmation that heritage education guarantees the attribution of values to tangible and intangible cultural heritage by society. In this manner, heritage education ensures that a society accepts and acknowledges the tangible and intangible heritage as its very own. This acceptance in turn assures the protection of tangible cultural heritage, or vitality of ICH, because the society will wish to take care of, enjoy, and transmit its accepted cultural heritage (Fontal and Gómez-Redondo, 2016).

As shown in Table 1, SDG 4 and target 4.7 provide an interesting point of departure for the present analysis of synergies between culture and SD. Here, within the general framework of education and lifelong learning of SDG 4, culture is associated with ESD and called upon, alongside other domains such as human rights and gender equality, to "ensure" that learners acquire the necessary knowledge and skills for SD. The text for target 4.7 is concise in its direct reference of SD towards promoting a "culture of peace and non-violence". This is also the case as it details the target's intent to appreciate "cultural diversity". On the other hand, the last call of target 4.7 of "culture's contribution to SD" is left vague, and open to interpretation.

As mentioned earlier, culture is intrinsic to human existence and people are cultural beings. Therefore, if culture is to contribute to SD, then a spectrum of opportunities arises because the manifold and diverse experiences of human existence are recognized as valid and possible pathways to contribute to SD. It can be inferred that this recognition allows a tripartite relationship to form between culture-education and SD, and that SD becomes more people-based.

This tripartite relationship of culture-education and SD has the potential to release more synergies. In spite of this, neither the 17 SDGs nor its associated global indicator framework of **231** unique indicators (UNDESA, 2022) reflects these synergies extensively and adequately. This expanded and more resourceful approach to understanding the synergies between culture-education and a people-based SD has more recently been manifested with the selection of UNESCO's suggested voluntary thematic indicators to measure and monitor the contribution of culture to the SDGs (UNESCO, 2019). In the publication introducing twenty-two Culture|2030 Indicators, the word "education" features 141 times. One of the four transversal thematic dimensions constituting its conceptual framework is "Knowledge and Skills" (UNESCO, 2019).

This dimension includes a total of five indicators with an educational component: ESD, cultural knowledge, multilingual education, cultural and artistic education, and cultural training. Based on the document analysis above, it can be inferred that the introduction of the twenty-two Culture 2030 Indicators is a recent development that reveals a major shift towards acknowledging the synergies between culture-education and people-based SD.

The absence of acknowledgement for the diverse contributions of culture for SDGs has also prompted scholars to advocate for the inclusion of culture in the discourse on ESD. For instance, the authors Batista & Andrade (2021) declare that for comprehending the challenges posed to the SDGs on different dimensions – economic, environmental, social, cultural – it is also necessary to understand the relationship between said dimensions. They assert the critical importance of biocultural diversity, and define the latter as the indivisible nexus and the existent synergies between linguistic, cultural, and biological diversity (Batista & Andrade, 2021). From their perspective of biocultural diversity, all species, languages and cultures are valued as heritages of humanity, and as such, the balanced use of environmental resources is encouraged (Batista & Andrade, 2021). They put forward the affirmation that ESD entails educating for biocultural diversity because "concerns associated with the social, environmental, and economic spheres are faced based on a personal, linguistic, cultural, and environmental history to consider, respect, value, and to preserve" (Batista & Andrade, 2021). Poole (2018) reasons along the same lines, arguing that the dynamics between cultural heritage and SD are a gap of the SDGs that have remained unaddressed. Poole broadens the discourse by adding the notion of biocultural heritage. For Poole (2018), biocultural heritage is the wealth of cultural memory and heritage, language, values, and ecological knowledge (local ecological knowledge (LEK) and traditional ecological knowledge (TEK)) carried by human culture and accumulated over time and generations. Poole (2018) proposes that the loss of biocultural heritage is an indirect driver of changes in the ecosystem leading to unsustainable practices (Poole, 2018). If cultural heritage containing LEK and TEK is lost, then so too is the tangible and intangible knowledge about environment, culture, and language that affects the well-being of all living creatures. Ultimately, this loss is a key driver of environmental crises and the subsequent creation of poverty (Poole, 2018).

This dialogue is central to the issue at hand – culture's contribution to SDGs – and especially with regard to ESD. The above discussion affirms that individuals facing the current social, environmental, and economic sustainability issues are, after all, people with specific cultural and linguistic belongings, cultural beings that have a relationship with their surrounding environment. The implication here is that the general discourse of sustainability must not only acknowledge the condition of people as cultural beings, but more importantly, seek to understand and value cultural heritage as a condition to achieve sustainability.

These extrapolations regarding culture and education indicate that it is imperative to incorporate a cultural dimension to the SDGs if SDGs are to attain a more holistic outlook. Indeed, the Convention for the Safeguarding of the Intangible Cultural Heritage (henceforth: The 2003 Convention) affirmed already at its inception in 2003 that sustaining ICH is regarded as a "guarantee" of SD: "Considering the importance of [ICH] as a mainspring of cultural diversity and

a guarantee of sustainable development" (The 2003 Convention, 2020). This notion is repeated in its Operational Directives (Chapter VI, "Safeguarding ICH and Sustainable Development at the National Level"), Article 170 as it states "State Parties shall endeavour ... to recognize the importance and strengthen the role of [ICH] as a driver and guarantee of sustainable development" (The 2003 Convention, 2020). Instances of success are those in which culture observably bridges the gap between SDG policy, goals, and practice. In other words, culture is a means to achieve human development. For instance, interventions for health and well-being (SDG 3) are most effective or sometimes the only resource when they are designed with a cultural approach and are responsive to the local cultural context (Hosagrahar, 2017). Another example are the arts (theatre) as a tool for communicating HIV/AIDS public awareness campaigns in locations where cultural taboo subjects prevail (Ruigrok, 2009).

It is inferred from the above that keeping the vitality of cultural intergenerational knowledge constant and shared over time, from one generation to the next, is of utmost importance for a people-based SD. However, especially regarding ICH, intergenerational sharing of knowledge is inherently fragile because it depends on memory and continued practice (Melis and Chambers, 2021). Moreover, safeguarding ICH requires human, economic, and material resources (Celi and Moore, 2015). These arguments establish the importance of undertaking conscious efforts in ESD to share cultural knowledge with future generations, which youths are a significant part of. For the youth to benefit from culture and to gain cultural empowerment, culture needs to be an integral part of ESD and SDGs. Therefore, the next section will focus more on the involvement of youth in the SDG discourse and their role in achieving them.

Culture and Youth Empowerment

As shown in Table 2, the word "youth" appears a total of nine times in the SDG texts (UNDESA, 2022). Apart from SDG 4, youths are also mentioned in SDG 8 and SDG 13. They are related thus not only to education but also strongly to employment and decent work, and, on a lesser scale, to action to combat climate change.

Table 2 SDG Text Containing "Youth"

Goal	Target	Indicator
Goal 4. Ensure	4.4 By 2030, substantially increase	4.3.1 Participation rate of
inclusive and equitable	the number of youth and adults who	youth and adults in formal and
quality education and	have relevant skills, including	non-formal education and
promote lifelong	technical and vocational skills, for	training in the previous 12
learning opportunities	employment, decent jobs and	months, by sex.
for all.	entrepreneurship.	
	4.6 By 2030, ensure that all youth	4.4.1 Proportion of youth and
	and a substantial proportion of	adults with information and
	adults, both men and women,	communications technology

	achieve literacy and numeracy.	(ICT) skills, by type of skill.
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.	 8.6 By 2020, substantially reduce the proportion of youth not in employment, education or training. 8.b By 2020, develop and operationalize a global strategy for youth employment and implement the Global Jobs Pact of the International Labour Organization. 	 8.6.1 Proportion of youth (aged 15–24 years) not in education, employment or training. 8.b.1 Existence of a developed and operationalized national strategy for youth employment, as a distinct strategy or as part of a national employment.
	International Labour Organization.	strategy.
Goal 13. Take urgent action to combat climate change and its impacts.	13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities.	

Source: UNDESA (2022)

An outlook of future opportunities of culture and SD must focus on youth given the critical characteristics of this group. According to the United Nations, in 2018 the worldwide number of young people was 1.8 billion, with approximately 90% living in developing countries and representing a large segment of the population (UN, 2018). This youth generation will experience in one way or the other the ubiquitous process of globalization. Among many of its impacts, globalization is known to create alterations in cultural ecology and changes in cultural practices (Lopes, 2020; Guo, 2020; Rodil and Winschiers-Theophilus, 2016). In the discourse of some scholars, globalization presents a threat to local cultures because globalization terminates autochthone cultures, amalgamating and homogenizing different cultures into a hybrid multiculture (Guo, 2020; Mahfoodh and Alhashmi, 2020). In the view of others, globalization as a cultural wave poses a threat to individual cultures, endangering cultural heritage and diversity (Medina-Carrión et al., 2018) thus causing ethnophagy (Díaz Polanco, 2011). Ethnophagy dissipates Indigenous cultures because as a process it causes "a smooth transition to the dominant culture through which differences are erased over time" (Despagne, 2013). Whether globalization is understood as either a homogenizing, erasing, hybridizing effect or as ethnophagy, current developments give strong reason to predict that globalization will continue to impact local cultures. Consequently, current youth generations will continue to experience impacts in their cultural environment. The concept of youth empowerment is translated by the UNESCO as improved access to multilingual information and sources of knowledge, enhancing ICT skills, and facilitating youth with disabilities to access ICT training (UNESCO, 2014). Based on observations from literature on the present subject, this paper suggests that involving youths in projects founded on the tripartite relationship of culture-education and SD creates a form of cultural empowerment for youths. This synergy presents the youth with a potential to achieve SD.

A synthesis of the reviewed literature on studies involving culture, youths, and youth empowerment reveals that the levels of youth involvement in cultural heritage projects differs widely across different case studies and contexts. Observably, three patterns emerged from the reviewed literature: Youth as passive receptors of cultural heritage, youth as active participants in cultural heritage, and youth as leaders of community heritages initiatives.

Youth as Passive Receptors of Cultural Heritage

The first category refers to projects designed for youths, but without the active co-design, leadership or decision-making of youths in the project. Five examples stand out from the literature review.

Culture offers youth opportunities to become empowered by furthering and developing their skills in the arts. Receiving heritage education as part of formal education can raise the youth's employability or their ability to become entrepreneurs. Examples are in Argentina, as the Teatro Argentino de La Plata in Buenos Aires offered vocational training to 610 unemployed adults and youths in performing arts skills (Hosagrahar, 2017). A similar example of cultural heritage combined with vocational training was the Syrian Stonemasonry Training Scheme, funded by the British Council and implemented in Northern Jordan. The beneficiaries were Syrian and Jordanian students, especially youths from the Syrian refugee community. The project's objectives were to engage youth in cultural heritage by learning conservation and stonemasonry skills, while also supporting the preservation of Syria's war-damaged heritage. The project also sought to engage primary school aged children by offering them six one-day workshops. In the outcomes and results, the British Council listed that the project formed a cohort of tradition bearers, access to employment for marginalised groups, and enhanced cohesion between Jordanian hosts and Syrian refugees (The British Council, 2018). A further example is the project proposal put forward by Coscia & Rubino (2021) to introduce a social dimension to ongoing projects of built heritage by including NEETs (youths Not in Education, Employment, or Training) for generating a positive social impact. All three above-mentioned examples are similar in that they have measurable social outcomes and impacts. For example, in the case of redeveloping historical farmhouses in Italy with the social inclusion of NEETs, Coscia & Rubino (2021) suggest as indicators the percentage of youths in an employment six months after program end, the number of volunteers participating, and the levels of awareness of heritage. This suggestion would also be applicable to the first two listed projects of vocational training for youths in cultural heritage projects.

The historical and ethnographic investigation by Lai (2020) examined the potential of urumi mēļam, Tamil folk drumming, for engaging and empowering Tamil Hindu youths-at-risk by keeping them from engaging in criminal behaviour in Singapore. Following the music and youth empowerment discourse, the author examines how engaging with Tamil folk drumming presents an opportunity for the Tamil Hindu youths' empowerment. The author concludes that empowerment is made possible because the youths receive training for learning the required instruments and songs to become ritual music specialists, and because they perform collectively,

and earn the respect of the Tamil Hindu community in Singapore by doing so. Moreover, the author points out that for the youths, participating in rituals for Tamil Folk Hindu deities is associated with certain spiritual beliefs. The youths believe their performance confers them with blessings, that it can ease the granting of wishes, and that it invokes powers to eliminate harmful energies (Lai, 2020).

In Kim's (2015) case study of the Tatebayashi Noodle Grand Prix festival in Japan it is mentioned that university students and young people from local and regional middle and high schools voluntarily participated as helpers. After their first-hand experience of the festival, the study found that the youth volunteers had increased community pride and heightened sense of belonging. These studies show that the cultural sector is a source for acquiring skills for enhancing the employability of youths through education and training, that it provides a common ground to nurture social cohesion with the local community, and that it can also be a source for spiritual well-being.

Youth as Active Participants in Cultural Heritage

The second category involves projects where youths had an active, decisive role, and either codesigned or partly led cultural projects.

An example of youth as active participants in cultural heritage projects is a cross-generational activity consisting of learning and collecting memories, presenting how schoolchildren can support and interact with senior citizens to bridge the digital divide (Dibeltulo et al., 2020). Taking cinemagoing memories as an element of Intangible Cultural Heritage (ICH), the project's main aim was to foster digital cross-generational encounters between schoolchildren and senior citizens. Thereby, older generations would also by empowered by sharing the ownership of their cultural heritage while also engaging with ICT skills. The study utilized the online resource Historypin. Historypin is a web-based, user-generated archive of crowdsourced historical material. The senior citizens were novice users of the online archive Historypin. Five senior citizens volunteers above the age of sixty-five years met with eighteen middle school students for the project. Youths took the key role of moderators and data collectors as they helped the volunteers share their cinematic cultural heritage on Historypin. In small groups, the students carried out video-interviews on their smartphones and uploaded the content onto Historypin. Additionally, the students showed the senior volunteers further ICH material, eliciting more memories through visual triggers. The feedback of the students was that it was a "valuable project" (Dibeltulo et al., 2020). More importantly, the authors mention that post-pilot activities revealed a continued interest of the students for the online platform and the project. After the project had ended, students interviewed their own senior family members about their cinema-going memories. Some students uploaded their family's cinema-related photos on Historypin, enriching further the community's cinemagoing ICH. Within the framework of the present paper, these outcomes points to empowering youths in three ways: the youths became agents of their community by helping to preserve ICH as digital cultural heritage; they gained insights into their own cultural heritage and community identity; and finally, they collaborated with older generations to support their accessibility and participation in digital environments. The study's post-pilot observation has an important implication for the present synthesis: by being proactive and continuing the project on their own (taking the initiative to interview family members and do uploads), the youth showed that they had a willingness to collaborate with family members on a topic of shared interest.

In a similar vein to Dibeltulo et al. (2020), Masucci et al., (2016) reviewed the outcomes and implementation of a university-community partnership, Building Information Technology Skills (BITS), involving high-school aged youths and designed to be culturally relevant. The youths were trained in geographic field methods in order to encourage civic engagement, to persevere in Science, Technology, Engineering and Math (STEM) disciplines, and to generate a digital archive of historic markers. The cultural dimension was introduced by focussing the youth-led and community-based geographic information system (GIS) on a set of historic markers of African American sites of interest in Philadelphia. The participants in this youth-led social action research initiative were local public high school students, students and faculty members at Temple University, and community members. The authors concluded that the engagement of the youth was successful. Evidence for this assessment was the project outcome: the participating high school students developed digital maps by collecting geospatial information through fieldwork, by using information from archives on historic markers and digital mapping technologies. In doing so, they gained digital technology skills, they also carried out geographic fieldwork and data analysis, and they experienced map-making and critical thinking throughout the process. Youth empowerment was a goal in several ways: through the digital inclusion and content creation of under-represented cultural and economic histories of African American heritage of North Philadelphia, by fostering STEM skills, by engaging with a university context, and by combining local cultural history and digital fieldwork. The authors note that various community stakeholders - teachers, parents, university course instructors - valued and used the digital maps created by students. Here, once more, it is observable that the success of the project was in part due to the project's cultural relevance, the digital mapping of African American historic markers, represented a shared interest of all stakeholders involved and motivated their willingness to engage on issues of common interest.

Youth as Leaders of Community Heritage Initiatives

The third and final category identifies youths as co-designing or taking leadership in cultural projects. Three examples stand out from the literature review.

First, a youth empowerment program for young Aboriginal women, aimed at gender equity in conservation through Aboriginal biocultural resource management in remote northern Australia (Daniels et al., 2022). In this three-year study, 60 participants aged between eighteen and thirty-five years acquired and practiced leadership skills. The project involved an Aboriginal-led adaptive co-design approach, and a "learning by doing" approach. Pre and post-tests of plant and cross-cultural animal knowledge were conducted to investigate learning gains. The results showed the significant learning gain in twenty species in three languages spoken by the Ngukurr *Yangbala* Rangers. Leadership was expressed e.g., through community engagement with the Ngukurr School. The project's Ngukurr *Yangbala* Rangers conducted fauna surveys, delivered workshops for senior classes, and helped the senior school class complete a certificate in conservation and

land management. Besides community engagement, the participants experienced leadership by one-on-one mentoring through local Elders and Rangers, presenting their work at conferences, and completing training on leadership and confidence building. An outcome of the project was that the youth acquired employment and progressed into higher education programmes. The project also helped to link Aboriginal and non-Aboriginal knowledge as a concept of "two-way knowledge and skills" (Daniels et al., 2022). This represents a decisive empowerment approach because it is culturally inclusive as it acknowledges and integrates local levels of education into SD.

Second, in the study of Kope & Arellano (2016), the authors applied the model of Critical Youth Empowerment (CYE) to explore Indigenous youth experiences in a Youth Leadership Program (YLP) for Indigenous resurgence in Whitefish River First Nation (WRFN), Ontario, Canada. The participants of WRFN in the YLP program belonged to two age groups, 9 - 13 and 14 - 18-yearolds. Using an experiental learning approach, each YLP program module aimed for the participating youth to plan and deliver a youth led-event (traditional games, outings, crafting, intergenerational sport tournaments). The youths developed the events and participated in all stages of their created events from fundraising to the implementation stage. Leadership and empowerment were enhanced as youth members became older, by being encouraged to use their acquired learning from YLP to apply it to decision-making situations in their community for improving power-sharing between them and adults. In their study of youths that participated in YLP, Kope and Arellano (2016) also identified a wide range of leadership qualities and empowerment of youths: in their capacity for improved critical reflection on their interpersonal lives; by empowering their community as they helped foster intergenerational relationships (e.g. using their leadership skills to plan and facilitate intergenerational events, giving back to the community by coaching and helping in sport tournaments); and by forging intercommunity friendships in youth symposiums.

The authors point to one expected outcome that was not successful. In examining the youth's capacity for engaging in critical self-reflection and socio-political processes of resurgence, the authors found that youths first had to recognize and overcome trauma. In observing the involvement of youth and their interest in participating in cultural ceremonies and intergenerational learning, one of the main findings of the authors is that culture and traditions were central for youth empowerment. The authors discuss that therefore, youth empowerment can only be complete if accompanied by practices to fortify cultural elements such as cultural identity, philosophy, Indigenous knowledge, values and spirituality. Thus, they conclude that for empowerment to be critical and effective for social change, it must rest on cultural and spiritual re-grounding instead of solely in terms of socio-political mobilization.

Third, for a qualitative study of the cultural importance of forest products, Johnson et al., (2021) partnered with Alaska Native Tribes and engaged local youth programs in the research work for the heritage project. Sixteen members of the youth group Alaskan Youth Stewards (AYS) Program aged 14 to 21 years were provided with training on basic interviewing and research procedures. The youth cohort then posed relevant community discussion questions for interviews, they contacted the interviewees, led discussions with community members, and recorded responses

into the project's data collection online app. Eight youth interns also carried out field activities with culture bearers (carvers and weavers), and helped to set up a two-year seedling experiment. The youths led a total of 58 community discussions in 11 communities.

The authors found that youth researchers engaged with their community by leading discussions with culture bearers, elders, non-government workers and government agency employees. The collected messages and reflections post-discussion revealed that the project experience inspired youth researchers to be more active stewards of their land and culture. The study also found that Alaska Native youth-led community discussions across Alaskan communities seemed to generate a more culturally relevant dialogue than with researches that were not directly linked with Alaska Tribes. Apart from the added benefit for the youths of gaining and sharing traditional ecological knowledge and ecosystem services, the youth engagement itself presented a "powerful communication link" between local communities and official land-management agencies.

It is noteworthy that all three studies can be categorised as a youth-driven approach for decolonisation purposes. Engaging youths as leaders supports the argument that culture can help share communication because it is based on common values, an important aspect of SD. It can be concluded that the above-mentioned culturally integrated approaches of youth empowerment initiatives are multi-layered and interdisciplinary. They typically involve various stakeholders, interests, and disciplines. These observations extrapolated from the previous three examples have implications for the potential of youths in achieving SD that reach further than the examples presented in subsections 3.2.1 and 3.2.2. The potential of culturally empowered youths to achieve SD resides in that they can fulfil leadership roles and become a 'nexus' between generations and stakeholders within their social environment. As a 'nexus', the youth represent shared interests and values for their community. When the youth become an axis around which information revolves, they are able to initiate dialogues in community between generations and between different stakeholders.

In the present paper, the review of studies on culture and youth empowerment has shown the potential of culture for SD beyond a simplistic and limited relation of culture-education. Culture, as an intrinsic part of human existence and experience, can be leveraged in multiple ways to empower, educate, and preserve knowledge that is vital for sustainable ways of life. It can be concluded that youth involvement in cultural heritage projects also leads to cultural empowerment, as the youth, representing future generations, are empowered. However, most of the presented and reviewed studies do not make explicit mention of ESD or ground their studies in theories of learning. The following subsection presents some recommendations for learning theories and pedagogy that can be coupled to holistic approaches of studies of culture, ESD, and peoplebased SD.

Discussion

In section 3.2.1. youth as passive receptors of cultural heritage, the reviewed cases had instances of vocational training and musical training. In section 3.2.2. youth as active participants in cultural heritage, the reviewed cases involved youth in middle school and high school and the examples

were thus part of formal education. In the third section 3.2.3 youth as leaders of community heritage initiatives, one case has a "learning by doing" approach, one an experiential learning approach, and in a third example the youth engaged in research work without following a specific learning theory. In the reviewed cases, the youth involvement in cultural projects also represented instances of advancing SD. However, except for the study on forest products by Johnson et al., (2021), the learning they experienced was not explicitly related to ESD, nor measured or categorized as such.

Firstly, directly correlating such studies with ESD and the SDGs would present an advancement because the scholarly landscape on the SDGs would become more transparent and measurable. Secondly, grounding youth empowerment initiatives on established learning theories would provide ESD with a scientific foundation. Applying scientific knowledge on learning and teaching to culturally integrated educational approaches would have the added value that ESD projects would be scientifically informed in their project design and provide learning assessment, thus measuring learning results and means to measure project outcomes.

For future outlooks, a learning theory that can be applied is the collaborative learning approach rooted in Vygotsky's social constructivism (1978). From a collaborative learning perspective, small groups of learners with varied performance levels work together, mediated by cultural means and artifacts, and collaborate to create a product, find a solution to a problem, or complete a task (Laal and Ghodsi, 2012). This learning theory is fitting e.g., for communal learning of ICH elements when it involves a limited number of participants (e.g., community members of a village, culture bearers and youths) who must collaborate with the goal of teaching ICH knowledge to future culture inheritors, or to create a cultural product. Built on social interdependence theory (where the results of learners are affected by their own and others' actions), some outcomes can be classified in terms of the quality of interpersonal relationships (Johnson and Johnson, 2009). Laal and Ghodsi point to further benefits of the collaborative learning approach as they conclude that typical outcomes of collaborative learning are higher achievements, more caring and committed relationships, social competence and self-esteem. One of the expected outcomes and main social benefits of collaborative learning is that it develops learning communities (Laal and Ghodsi, 2012). These social learning systems can further be analysed as communities of practice (Wenger, 2000). Creating communities of practice is not only a desirable outcome for sustaining social cohesion of the community but also suitable for communities based on oral cultures. For instance, as Daniels et al. (2022) note, Aboriginal knowledge is largely taught orally (Daniels et al., 2022). Moreover, a community of practice approach has elements that would enhance the design of culture-related ESD. These elements are: events that bring the community together; multiple forms of internal leadership to develop the community; a rich connectivity among its people; a membership that is significant but its number still allows participation: learning projects that fill gaps in community practice; and lastly, artifacts that remain useful as the community develops (Wenger, 2000).

As established earlier, culture can permeate all aspects of people's lived experience. In this sense, not only the content that is the object of learning can be related to culture but also the very act of teaching itself contains cultural aspects. Therefore, culture is also an aspect of pedagogy that can be taken into consideration, especially when the teaching is for ESD. Culturally relevant pedagogy, the theoretical model of Ladson-Billings (1995), takes into account the cultural patterns and backgrounds of teachers and learners, and the broad social and cultural context of students. It proposes teaching must meet three main criteria: support student learning, nurture cultural competence, and develop critical consciousness (Ladson-Billings, 1995). In this educational approach, teachers include the student's culture as "official knowledge" and thereby help them assert and take pride in their cultural identity (Ladson-Billings, 1995). This pedagogy is an example of how culture-education and people-based SD is strongly interrelated: culturally integrated approaches can be applied not only on *what* is taught (cultural and artistic education, heritage education, ICH), but also *how* it is taught (culturally relevant pedagogy, communities of practice approach) depending on *who* is being taught (individuals with an intrinsic cultural experience).

In sum, the tripartite relationship of culture-education and SD can be illustrated as in Figure 1. If local or regional youth- and ESD centred initiatives take a culture-based approach or are culturally informed, then synergies are created. These synergies in turn generate a major traction towards achieving results in SD.



Figure 1. Visual Diagram of Synergies of Culture-education and Sustainable Development

Source: the authors

Conclusions

This paper is focused on exploring the synergies between culture, SD, and youth. The paper presents an integrative literature review of selected studies that provides an overview of the interrelationship between culture-education and SD.

The review reflects on how culture is underrepresented in the SDGs, and why this absence matters for SD. It further seeks to identify how the tripartite relationship of culture-education and SD can create synergies, empower youth and give youth the potential of achieving SD.

The analysis provides strong evidence to support the argument that youths can be empowered through culture and possess a high potential for achieving SD. The reviewed studies were classified according to the level of youth engagement. A major implication of this subsection is that culturally empowered youths in leadership roles are a potential for achieving SD because they become an information and support agent in their community.

Additionally, the presented studies showed a recurrence of the element of collaboration and collective learning. Mutual engagement was present in the study on digital engagements of older adults with cinema-related ICH as a partnership across generations between the young and elderly, promoting thus intergenerational dialogue through shared interests (Dibeltulo et al. 2020). In Masucci et al. (2016), a collaborative, cross-disciplinary project took place with amongst several community stakeholders (e.g., neighbourhood and community organizations, families, youth). Collective learning also featured in the Aboriginal-led, co-designed and cross-cultural project Ngukurr *Yangbala* (Young People) Project in remote northern Australia (Daniels et al., 2022). It also included "two-way knowledge and skills", linking the knowledge and science of Aboriginal and non-Aboriginal communities and presenting thus a kind of mutual engagement between cultural paradigms of knowledge.

These observations lead firstly to the conclusion that culturally integrated approaches in SD can provide a common ground of shared values and common interests that allow different stakeholders to collaborate and thus enhance SD. Secondly, the element of collective learning allows to draw the conclusion that the collaborative learning approach and the communities of practice approach can be used as a framework of reference for designing and evaluating projects on culture and ESD. Since pedagogy can also be viewed through the lens of culture, ESD can also rely on culturally informed theories of teaching for culture-sensitive projects. Lastly, these arguments also lead to the conclusion that cultural approaches can be considered across all 17 SDGs because people as cultural beings will experience SD through the lens of their cultural heritage.

The strength of the reviewed literature is that scholarly texts provide a vast variety of contexts in which SD is being practiced with the help of culture and ESD. The present paper highlighted some examples containing studies of youth empowerment and reflections on the synergies between culture-education and SD. In this way, this paper underscores the vitality of culture in achieving the SDGs, especially with the focus on youth and ESD. Future studies must look into how to take

advantage of the synergies created when cultural approaches are considered in advancing people-based SD. The importance of these observations is immediate given the challenges present in post-pandemic outlooks. Estimates indicate that the economic impact of the Covid-19 pandemic on education could cause approximately 24 million children and youth, from pre-primary to tertiary education, to drop out of school (Klaassen, 2021). The cultural sector offers resourceful opportunities to collaborate with stakeholders sharing common interests to further youth empowerment outside of formal education.

The limitation of this paper is its sole focus on educational aspects of culture and youth. Further studies are needed to explore other equally important yet understudied aspects of culture and SDGs, such as the informal economy of the cultural sector, the labour legislation, and lack of social protection of cultural workers and professionals.

Acknowledgements

The authors of this paper are grateful to the Grant for Global Sustainability (GGS) and the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) of Japan for the funding and support of the present research.

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Building Capacity and Awareness for the UN Sustainable Development Goals Through Project-Based and Community-Engaged Pedagogies

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Abstract

Purpose - The key sustainability competencies are fundamental to sustainability transformations. The purpose of this study is to investigate the effectiveness of project-based and communityengaged pedagogies in supporting student development of all key sustainability competencies. Additionally, the study examines whether the UN SDGs provide an appropriate framework to support engagement with the breadth of sustainability topics and increase awareness and support of the goals within the community.

Design - This case study triangulates scaled self-assessment, performance observation, and regular course work in an undergraduate interdisciplinary sustainability course to gain insights into how all key sustainability competencies can be developed through recommended pedagogies.

Findings - Project-based and community-engaged pedagogies are supportive of key sustainability competencies development. The act of engaging with an interdisciplinary group towards achieving a common goal created effective learning opportunities for students. However, the project-based and community-engaged pedagogies cannot be completely separated from the context of the course. The use of the SDGs to guide community partner participation and project development was effective in increasing awareness of the goals among students and community partners.

Implications - These findings support the use of project-based and community-engaged pedagogies to facilitate student development of key sustainability competencies.

Originality - This study demonstrates that using the SDGs to guide community partner participation and project development is effective both in facilitating a wide range of projects from the identified areas of sustainability: environment, economic, social, and cultural, and in increasing awareness of the goals among students and community organizations.

Keywords: sustainability competencies; sustainable development goals; community-engaged learning; project-based learning; pedagogies

Purpose

The world is facing multiple sustainability crises. The United Nations (UN) Sustainable Development Goals (SDGs) (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2017) present a vision of a desired future. However, without leaders who can successfully navigate the complex realities of current and future sustainability scenarios the world will be unsuccessful in achieving the SDGs. The literature offers both key sustainability competencies, identified as essential to leading transformative change (Redman and Wiek, 2021) and recommendations on pedagogies (Lozano *et al.*, 2017; Evans, 2019). By integrating the SDGs within a community-based teaching and learning context educators have the potential to create real-life, tangible learning opportunities to support the development of sustainability competencies and increased participation and support for the SDGs now and in the future.

Education experiences contribute directly to Sustainable Development Goal 4, Quality Education, Education for sustainable development and global citizenship. This study leverages Target 4.7 to "ensure that all learners acquire the knowledge and skills needed to promote sustainable development" (United Nations, 2015, Goal 4) by examining both the pedagogy and the assessment of sustainability competencies. The goal is to educate the leaders, so they are prepared to act in this UN declared Decade of Action 2020-2030 and throughout their lives. This study contributes to discussions of how to teach and how to assess sustainability education. It is essential that citizens can identify problems, solutions and actionable approaches that contribute to social, economic, environmental, and cultural sustainability. If these underlying competencies are lacking, citizens will not be able to identify and take the required actions to achieve the goals, that is why sustainability education matters.

Key Sustainability Competencies

Although sustainability is a recognized academic field and profession, and there are many sustainability programs established at universities around the world, consensus on program level learning objectives and the key sustainability competencies required to achieve those objectives has been a challenge (Sterling *et al.*, 2017; Trencher *et al.*, 2018; Brundiers *et al.*, 2021). Brundiers *et al.* (2021) have attempted to address this lack of clarity and consensus by collecting feedback from 14 international sustainability experts on the Wiek *et al.* (2011) and Wiek *et al.* (2016) developed competencies. Sustainability experts generally agreed with the existing competencies, but suggested refinements including additional competencies, specifying learning objectives, and recommending greater interconnectedness (Brundiers *et al.*, 2021, p. 18). Redman and Wiek (2021) also found that the existing competencies framework was well accepted in the literature but required some renaming to support understanding and the addition of new competencies suggested by Brundiers *et al.* (2021).

The competencies used in this study, were those put forward by Wiek *et al.* (2011), which are the most cited key sustainability competencies (Trencher *et al.*, 2018, p. 831; Brundiers *et al.*, 2021, p. 18). At the time of the development of this study, neither Brundiers *et al.* (2021) nor Redman

and Wiek (2021) had published their studies recommending additional competencies. The competencies used within the context of the current study are in Table 1.

Competency	Description
Systems-thinking	The ability to analyze complex systems, taking different domains – such as society, environment, economy, and culture – and scales – local to global – into account. Feedback loops, leverage points, and other systemic features are considered.
Anticipatory (renamed Futures- Thinking in Redman and Wiek, 2021)	The ability to think about the future both in terms of forecasting from current scenarios and in anticipating the future outcomes of sustainability action plans or strategies.
Normative (renamed Values- Thinking in Redman and Wiek, 2021)	The ability to map, apply, and negotiate sustainability values, principles, goals, and targets particularly in relation to current and/or future states of systems.
Strategic	The ability to apply knowledge of complex systems to construct and test action plans for sustainability
Interpersonal	The ability to collaborate and participate in meaningful ways to contribute to teams and work with diverse stakeholders

Table 1: Definition for Each Key Competencies for Sustainability

With general agreement regarding key sustainability competencies, it is pertinent to identify the most appropriate pedagogical strategies for developing these competencies (O'Brien and Sarkis, 2014; Wiek and Kay, 2015; Trencher *et al.*, 2016; Ortega-Sanchez *et al.*, 2018). Project/problembased learning, often with a community partner is frequently used (Evans, 2019, p. 5542) and recommended as an effective pedagogy for sustainability education (Cörvers *et al.*, 2016, p. 357). Trencher *et al.* (2018) found that practice-oriented sustainability masters programs which emphasize real-life problem solving and learning opportunities, often through projects with external partners "demonstrat[ed] higher success in building interpersonal, strategic and normative competencies" (Abstract).

This perspective is supported by de Haan (2006, p. 22) who argues that competence-oriented education should focus on output, or what is learnt, versus a conventional syllabus approach of focusing on input, or what is taught, to incorporate problem solving and real-world project-based approaches required by sustainability challenges. This corresponds to the idea of competence as the ability "to perform a task or an activity consistently over time and in different situations" (Green and Levy, no date, What do we mean by competence?, para. 3). Project-based, problem-based, and community-engaged learning address outputs because they are not focused on specific

subjects that students need to study, but on asking "what problem-solving strategies, concepts and abilities for social action they should have" (de Haan, 2006, p. 22).

Finally, Lozano *et al.* (2017) found that problem/project-based learning and community service learning (related to community-engaged learning) were covered the greatest number of different competencies. This aligns with Cörvers *et al.* (2016, p. 356) who also suggest that problem/project-based learning offer a broad opportunity to develop sustainability competencies, particularly when engaged with "real-world sustainability issues".

Redman and Wiek (2021) argue that the competencies are fundamental to achieving the societal transformations that are required by the SDGs. Further, the values that underlie the SDGs are fundamental to the successful application of the competence within a sustainability context (Brundiers *et al.*, 2021). The SDGs are intended to address current real-world challenges. Therefore, using the SDGs as a framework for developing key sustainability competencies is appropriate. Identifying and applying effective pedagogical strategies for developing sustainability competencies is thus vital to achieving SDG 4.

The UN SDGs require sustainability competencies as per UNESCO's (2017) "Education for Sustainable Development Goals: Learning Objectives". There is much written about how the SDGs can be incorporated into developing sustainability competencies, with Brundiers *et al.* (2021 p. 20) being a recent example. There is no shortage of articles and case studies examining the use of project/problem-based thinking and learning to address the challenges that must be overcome to achieve the SDGs, some examples include, Lehmann *et al.* (2008), Yasin and Rhaman (2011), and Dobson and Tompkinson (2012). However, the authors were not able to find any case studies specifically discussing using the SDGs to guide and design project/problem-based community-engaged learning. This case study built on the literature discussing the usefulness of project/problem-based community-engaged learning in teaching the SDGs, (Brundiers *et al.*, 2010; Konrad, *et at.*, 2021; Cörvers *et al.*, 2016), to inform the use of the SDGs in community partner selection, problem definition, and evaluation of the projects by students and their professor.

Research Questions

The primary research question for this study is:

• In what ways does project-based, community-engaged learning contribute to the development of key sustainability competencies?

An additional question asks:

• In what ways does using the United Nations Sustainable Development Goals to frame community-engaged learning contribute to awareness of the goals among students and community partners?

Design

A case study methodology was used to investigate the use of project and community-based learning pedagogical strategies for developing sustainability competencies within an undergraduate sustainability course. A case study is appropriate because the goal of the study is to examine the pedagogical strategies within the context of a real-world course (Yin, 2018, p. 15). The course context of the case includes using the United Nations Sustainable Development Goals to solicit and select community partners, as well as a framework for student reflection and instructor assessment. The structure of the course and the instructor herself cannot be separated from the use of specific pedagogical strategies.

Specifically, the pedagogy used a type of experiential learning informed by constructionist theory, project-based, community-engaged learning. The definition of project-based, community-engaged learning used in this study is learning by actively working with a community partner organization to provide tangible contributions towards addressing community partner needs. This definition was informed by Evans (2019, p. 5542) and Brassler and Dettmers (2017, p. 2), and aligns with the definition from the host university's Careers & Experience office which provided support for identifying and recruiting community partners for the course (Careers and Experience, no date, "Community-engaged Learning", para. 2).

Course Overview

The course in question is an intermediate level online, asynchronous course geared towards addressing sustainability challenges through project-based, community-engaged learning that ran in Fall 2021 at an undergraduate postsecondary institution in Alberta, Canada. Students are introduced to the idea of sustainability competencies early in the course. The instructor then connects different activities and resources back to these competencies throughout the semester.

The course is interdisciplinary and open to all students regardless of program of study making it difficult to focus course content on a particular subject area. Thus, the focus is on the contentindependent key sustainability competencies as identified by Wiek *et al.* (2011). Sustainability challenges are complex and subject to change (Le Grange, 2011); therefore, focusing on competencies better serves course learning objectives such as being able to "evaluate goals, approaches, requirements, and tradeoffs for sustainability projects" (Primary Author, 2021, p. 2). All learners, regardless of background and field of interest, can develop skills that enable them to participate in and lead current and future sustainability projects.

There is substantial evidence (Brundiers *et al.*, 2010; Barth, 2015; Konrad, *et al.*, 2020) that pedagogies of project-based learning, which incorporates problem-based approaches, and community-engaged learning, are effective for learning sustainability competencies (Cörvers *et al.*, 2016, p. 357; Konrad, *et al.*, 2021, p. 537). All other course activities are designed to support the successful development of projects for community partners while facilitating student learning, experience, and engagement.

The SDGs take a multifaceted perspective on sustainability including social, economic, environment, and cultural components. Thus, framing the call for community partners around the SDGs ensured that all projects could be situated within the broad context of sustainability. Community partners were recruited through the Career and Experiences Office at the institution. Potential partners responded to the posted call and submitted their desired topics/project area as well as identified applicable SDGs for their potential projects. The instructor and Career and Experiences staff then vetted the projects to ensure they would meet the requirements for the course in terms of scope, topic area, and final product. Table 2 identifies the focus of the community partner organizations, the target SDG(s) identified by the organization, and a brief description of the project.

Community Partner	Target SDG(s)	Project Description
Focus Area		
Municipal Airshed	3. Good Health and Well-Being	Development of social media
Monitoring and	13. Climate Action	campaign connecting air quality to the
Education	17. Partnerships for the Goals	SDGs
Rural Airshed	3. Good Health and Well-Being	Development of educational brochure
Monitoring and	17. Partnerships for the Goals	connecting air quality to the SDGs
Education		
Anti-Racism	10. Reduced Inequalities	Development of community resource
Education in Rural	16. Peace, Justice and Strong	kit to promote discussion of and
Area	Institutions	engagement with anti-racist practices
	17. Partnerships for the Goals	
Agricultural	2. Zero Hunger	Research report on agricultural
Research	Good Health and Well-Being	practices to improve soil carbon
Organization	12. Responsible Consumption and	sequestration
	Production	
	13. Climate Action	
	15. Life on Land	
Adult Literacy	1. No Poverty	Promotional video connecting
Organization	 Quality Education 	employment and business outcomes
	8. Decent Work and Economic	to increased adult literacy
	Growth	
	10. Reduced Inequalities	
Municipal	12. Responsible Consumption and	Research report on integrating social
Organization	Production	justice considerations into
Focused on Large-	17. Partnerships for the Goals	procurement policies
Scale Events	12. Responsible Consumption and	Research report on improving waste
	Production	diversion rates from large-scale events

Table 2: Community Partners, Target SDGs, and Project Description

Another significant characteristic of the course is the use of specifications grading for assessment. This is a form of mastery grading and is, therefore, better suited to the assessment of competencies (Nilson, 2014). Rather than students earning partial points on assessments, all assessments are graded as complete/revisions needed. This ensures that all students who earn
a passing grade in the course have reached base levels of competency (Nilson, 2014). This contributes to the real-life connections provided by the community-engaged learning by replicating professional work requirements. As a result, it is likely that more students were able to improve their competencies than may have occurred in a traditionally graded course. Indeed, this has been examined in an introductory sustainability course and shown to be the case (Wasnieski, *et al.* 2021).

Consent and Anonymity

Students enrolled in the sustainability course were asked to consent to participate in the research. Consent information was collected by the co-investigator and was not shared with the primary author and course instructor until after the appeals period following the submission of the final grades in the course.

Data Collection

In their review of the sustainability competencies assessment literature Redman *et al.* (2021) identify eight dominant approaches. They recommend combining assessment tools "to address the shortcomings of any particular assessment tool" (Redman *et al.*, 2021, p. 127). This triangulation of multiple sources of evidence is also described by Yin (2018) as a fundamental feature of case study research. As a result, this study used a mixed-method approach drawing on three areas of data collection: scaled self-assessment, performance observation, and regular course work (Redman *et al.*, 2021). Data collection occurred throughout the Fall 2021 semester.

Scaled self-assessment

Scaled self-assessment asks students to reflect on their own skills, ability, and knowledge, and rank themselves on a Likert scale. This is a common method for assessing sustainability competencies (Redman *et al.*, 2021). The survey instrument in this study was adapted from Molderez and Fonseca (2018) who used the tool following participation in a service-learning project and real-world experience. The tool was adapted by rewording items to allow for a preand post-test condition to address a limitation identified by Molderez and Fonseca (2018). One item was removed as it was not applicable to the current case. The questionnaire is based on the competencies identified by Wiek *et al.* (2011) with each competency represented by multiple statements. For each statement, students rated their agreement on a five-point Likert scale rating. Students also had the option of selecting 0 for "no experience."

Performance Observation

The engagement of community partners in the course provided the opportunity to include performance observation in this project. This was limited because the community partners were not necessarily familiar with sustainability competencies and covering this concept is beyond the scope of this study. However, as professionals working in fields that are related to the United Nations Sustainable Development Goals, they are familiar with the skills and attributes that contribute to their work. Thus, partners were asked generally if they noticed skills, activities, or competencies that are relevant to sustainable development. This data is not specific to individual students.

Regular Course Work

Regular course work is the least used method in assessing sustainability competencies (Redman *et al.*, 2020). This may be a result of course work that typically focuses on learning outcomes rather than competencies. The use of specifications grading in the current course, as well as the development of final projects for community partners, facilitates a focus on outputs in this course. Therefore, the regular course work is well positioned to provide evidence of competence.

Analysis

R (version 4.1.2) was used for the statistical analysis of the self-assessments. Each of the five competencies was analyzed individually and combined. Prior to the model fitting process, descriptive statistics (mean, standard deviation, median and interquartile range of scores before and after taking the course) were computed. A series of Wilcoxon signed-rank non-parametric tests were conducted to assess whether there was a significant improvement in the median competencies. Due to a low sample size, individual items from the questionnaire were not analyzed separately.

In both qualitative and case study research, it is generally recommended that the researcher begins qualitative data analysis while still collecting data (Merriam and Tisdell, 2016; Yin, 2018). Informal analysis of student work was done throughout the period of data collection to adapt the course to the needs of the students. This led the researchers towards the development of initial codes apparent in student work. These codes were then formalized and sorted into categories and then associated with the most applicable competency following the completion of the course. This final process was based on the material from students who had consented to participate in the research only; however, the original codes were all represented within this sample. The formation of categories followed an inductive process as described by Merriam and Tisdell (2016). Dedoose (version XXXX) was used to support the coding and analysis of qualitative data.

Findings and Discussion

Demographics

Participants were students enrolled in an intermediate course on sustainability challenges at an undergraduate university. Twenty-eight students consented to have their course work included as part of this research study. Base demographic data was collected. Most students in the course used she/her pronouns. A complete breakdown is found in Figure 1.

Students were enrolled in several different programs while taking this elective course. Figure 2 shows the breakdown by degree. Bachelor of Commerce is the highest number. The Other

category includes Bachelor of Science in Nursing, Bachelor of Design, Open Studies, and Certificate of Achievement in Sustainability.

Due to an administrative error, the prerequisite course was missed for the 2021/2022 year. As a result, some students did not have the prerequisite. This data is shown in Figure 3.



Figure 1. Student Pronouns



Figure 2. Student Program of Study



Figure 3. Prerequisite Course Completed

Developing Sustainability Competencies

This research presents the case study regarding the role of project-based and communityengaged learning in developing sustainability competencies. In addition, the impact of using the United Nations Sustainable Development Goals as the framework for engaging the community partners on student and partner understanding and capacity to act on the goals was investigated.

The sustainability competencies were based on Wiek *et al.* (2011). Redman and Wiek (2021) state that "the key competencies are *not* compiled as a *list* to select from" (p. 5). This matched the experience of the instructor in the course. While there were certain activities, resources, or projects that leaned towards specific competencies, it is difficult to tease all the different elements apart, nor should this be the goal. In what follows, the sustainability competencies, the opportunities to develop these competencies, and the evidence of that development, are separated, but the authors acknowledge that this is done to support readability and understanding rather than to represent the reality.

Pre and Post Self-Assessment of Sustainability Competencies

Twenty of the twenty-eight students completed both the pre and post self-assessment. The mean overall score of all 20 students increased from 104.6 (SD = 16.3) before to 118.1 (SD = 16.4) after taking the course. As summarized in Table 3, the median scores for each of the five competencies also increased from before to after the course. Wilcoxon signed-rank tests demonstrated statistically significant improvements for all competencies based on a standard p-value of 0.05: interpersonal (W = 118, p = .0005) systems thinking (W = 173.5, p = .0055), anticipatory thinking (W = 168, p = .00171), normative thinking (W = 153, p = .00015), and strategic thinking (W = 57, p = .01561) and overall scores (W = 163.5, p = .00037).

	Pre M ± SD	Post M ± SD	Pre Mdn <u>+</u> IQR	Post Mdn ± IQR	W	P-value
Competencies						
Interpersonal	25.7 <u>+</u> 2.74	27.9 <u>+</u> 2.22	25.5 <u>+</u> 4.0	28.0 <u>+</u> 4.0	118	0.00050***
Systems thinking	30.7 <u>+</u> 6.22	35.9 <u>+</u> 3.84	31.5 <u>+</u> 9.5	37.0 <u>+</u> 4.25	173.5	0.00550**
Anticipatory thinking	18.5 <u>+</u> 3.52	21.4 <u>+</u> 3.39	18.5 <u>+</u> 5.25	21.5 <u>+</u> 6.0	168	0.00171**
Normative thinking	6.50 <u>+</u> 2.40	9.00 <u>+</u> 0.86	7.0 <u>+</u> 2.5	9.0±2.0	153	0.00015***
Strategic thinking	8.65 <u>+</u> 1.23	9.30 <u>+</u> 0.92	8.5 <u>+</u> 2.0	10.0 <u>+</u> 2.0	57	0.01561*
Overall	104.6 <u>+</u> 16.3	118.1 <u>+</u> 16.4	107.5 <u>+</u> 22.3	123.0 <u>+</u> 23.8	163.5	0.00037***

Table 3. Comparison of Self-assessment Scores Before and After Taking the Sustainabilit	y
Course	

Note. M = mean, SD = standard deviation Mdn = median, IQR = Interquartile Range, W = Wilcoxon signed-rank test statistic. Significance cut-offs: * p <.05, **p<.01, ***p<.001

Self-assessment in this course was not simply a tool to measure competency development on behalf of the researchers. Self-assessment was included within the framework of the course to support what has been referred to as sustainable assessment (Boud and Soler, 2016). Within the context of sustainable assessment, assessment is viewed as one more tool that contributes to preparing students to be life-long learners after they leave formal education (Boud and Falchikov, 2007). Redman and Wiek (2021) critique the overreliance on self-assessment of competence based on questions of validity of self-assessments. However, self-assessment was framed to

students within the context of self-reflection to enable future learning and growth (Tamir, 1999). This was evident in student work. For example, Participant 14 stated:

The sustainability competencies really helped when it came to self-awareness within a group. Understanding my own strengths and weaknesses before beginning the project gave me a layout of my best qualities, I know I can contribute, and my worst ones that I can develop.

One student even recognized their own challenges with self-assessment:

Learning and developing sustainability competencies are a good reminder of how many factors can contribute to the success of a project. Self-assessment is not something that I'm good at, but it is valuable to take stock of personal strengths and areas for improvement. It's a good reminder that if we don't recognize our weaknesses, we can't improve them. (Participant 23)

The pre-self-assessment also contributed to helping students think about the breadth of sustainability challenges. As Participant 21 stated:

I believe the competencies in the surveys helped me consider what is involved in approaching sustainability from a social perspective. This helped me to consider where I am at regarding these competencies, and what I have yet to work on.

Upon reflection, I can see how the community partner projects helped to develop my skills in these competencies and solidify skills that I already had, such as leadership, communication skills, and thinking holistically about how our project can affect sustainability.

Thus, while we should be cautious in drawing conclusions based solely on the use of selfassessment, it is an important tool in sustainability education. It can support learners in becoming life-long learners who can adapt and grow in the face of changing sustainability challenges. This is summed up by Participant 3:

It gives us an overall understanding of where we are right now and how competent we are for certain projects. It helps us develop our weaknesses and also gives us awareness of what are our strengths so we understand what role we can take in the future sustainability projects and also how to overcome certain challenges.

Community-Engaged Learning and Sustainability Competencies

Redman and Wiek (2021) argue that all competencies need to be addressed and developed together for students to become "change agents" (p. 5). The quantitative results indicate that this has occurred within the context of the course in this study, as all competencies show significant improvement in the self-assessment. However, a key feature of this study is the triangulation of the self-assessment with the course work of the students, as examined by the instructor. Therefore, the self-assessed competencies will be discussed in relation to the course and specifically the community partner projects in the following sections.

Interpersonal

One of the characteristics of the present course is the diversity of the students: the course is an elective open to students from all faculties, as well as open studies students (those not registered in a program). As a result, the course offers an opportunity to work with more diverse teams than is offered in a discipline specific course. The community partner project forms the basis of the collaboration among students in the course. In other words, the team comes together to achieve a common goal based on their common interest in sustainability rather than their focus on earning a specific credential. This collaborative and interdisciplinary approach to advancing sustainability is fundamental to the demonstration of interpersonal competence (Redman and Wiek, 2021).

Two items of coursework were analyzed by the instructor to identify the development of interpersonal competence: group statements about collaborative work and individual summary statements regarding a round table activity. In the round table activity students presented their community partner projects with peers from different projects and collected feedback from and provided feedback to each other. Table 4 highlights examples of evidence that students developed interpersonal competence.

Students were asked to identify what they learned that they believed would have the biggest impact on their future decisions and options. Interpersonal was mentioned by 11 of 28 students, second only to systems thinking in terms of frequency. This growth was also reflected in the self-assessment data (W=118, p<0.00050). Students commented that they learned to look at diversity and disagreement as positives that can contribute to a more sustainable future. For example, participant 14 stated:

I've learnt that when people disagree, they do so because of their past situations, upbrings (sic), and everything that shaped them into the person they are today. Instead of turning it into a battle of who agrees and who disagrees, perhaps we should make a plan for a better future for everyone, and have everyone's voices heard so we can use every perspective and every angle to help us achieve our goals.

This statement illustrates how the student was able to approach disagreement as an opportunity rather than a challenge, which demonstrates interpersonal competence. Further, they indicated that this was an area of growth. This is in-line with what Konrad, *et al.*, (2021) found about the value of project-based learning for developing interpersonal competence.

Participant/ Group	Example	Instructor Analysis
Soil Carbon sequestration in Agriculture	Group statement about working collaboratively to create an interdisciplinary systems map: "each of our disciplines came together to bring ideas that may have been overlooked initially. We were able to discuss concepts and get a deeper understanding of the interconnections between elements. We cooperated to refine our map and disregard sections that we agreed did not contribute relevant details to our project."	Students demonstrated key skills for interpersonal competence such as "fostering self-efficacy for the self and others" (Evans, 2019, p. 5534). This is demonstrated by acknowledging that each person brought important ideas to the group and through discussion everyone deepened their understanding of the issues related to the challenge they were addressing
Participant 12	Round table summary: student reflected on the importance of thinking about who the audience is for their project and how that shapes what and how they write their report.	Student demonstrates awareness of the diversity of stakeholders in their project. The organization was looking for technical information that they could use to provide support to their stakeholders. As a result, the student reflected that the organization itself was the stakeholder that they needed to focus on, but that the other stakeholders should not be forgotten.
Participant 1	Round table summary: student described their thought process in re-evaluating the social media posts they had created for their organization. They discussed working on finding the balance between providing information, encouraging viewers to want to learn more, and engaging people with the posts.	Student demonstrates growing awareness of different potential audiences or stakeholders and working on providing options for people to engage at different levels.

Table 4. Student Examples and Instructor Analysis of Statements Indicating Development of Interpersonal Competence

Systems Thinking

Systems thinking was the most frequently identified learning that students thought would impact their future with 13 of 28 students mentioning it. However, systems thinking, while significant (W=173.5, p < 0.00550), was slightly lower than some of the other competencies with regards to the improvement throughout the course. The most likely explanation for this is that the 20 students who had completed the prerequisite course had all been exposed to systems thinking previously. Therefore, they likely had greater familiarity and comfort with the statements during the pre-self-assessment. This was not analyzed due to the small sample size.

Overall, the students stated that learning about interconnections and the importance of including other perspectives, which also touches on interpersonal competence, was something that greatly influenced their outlook. For example, Participant 10 stated:

I think that one of the biggest contributions of learning and developing sustainability competencies is my ability to now look at the bigger picture when taking on future sustainability projects and challenges. But when I say bigger picture, I mean the system I am working on as a whole, not just the end product I would want to get to, but how things are connected (like in systems mapping), and how each individual element in a project can have a specific effect on something else, whether that be an environmental effect or a societal or cultural effect.

Students create and submit systems maps individually based on the challenge their community partner was aiming to address (e.g., adult literacy, racism in rural environments, carbon sequestration through agricultural practices). If required, students completed revisions on their individual maps based on feedback and resubmitted. This ensured that students reached a base level of competency with both systems mapping and systems thinking in general. A sample student map is pictured in Figure 4.



Figure 4. Sample Individual Systems Map Examining Racism in a Rural Environment (Student 2)

The systems map assignment requires students to identify and describe feedback loops, leverage points, and the system's purpose. Students often struggle with feedback loops because the loops challenge the linear thinking that they are used to. Students are generally able to identify a causal relationship between elements, x leads to y leads to z. But they have trouble identifying how z impacts x. For example, student 15 initially described "the more reusable products, the better the environment" as a reinforcing feedback loop. The student identified the loop as reinforcing because both elements changed in the same direction.

The purpose is also challenging for students. Many students start thinking about the purpose of the system as the purpose for the organization, often summarizing the organization's mission statement as the purpose.

However, because the maps are based on a particular issue from an organization, observations of the organization enable students to better understand the system and systems mapping. For example, instructor guidance provided to the student regarding the feedback loop above encouraged them to think about how having a cleaner event space could influence event organizers' waste policies regarding reusable products. As a result, the student was able to revise their understanding about how the context, the environment, could influence policy regarding event materials

Similarly in identifying the purpose of the system, feedback encouraged reflection regarding what created a need for the organization. Therefore, students started to realize that the reason the

organizations existed was because the system was leading to circumstances that nobody wanted such as illiteracy, poverty, or climate change (Meadows, 2008, p. 15). Example statements demonstrating systems competence are shown in Table 5.

Table 5. Student Examples and Instructor Analysis of Statements Indicating Developmentof Systems Thinking Competence

Participant	Example	Instructor Analysis
1	Leverage Point: Alberta capital residences are directly affected by air quality. They also are able to influence policy and decision making by voting in policy makers with goals to create better air quality. Can put pressure on governments and NGO's to fund more research therefore educating more people	Student demonstrates awareness that leverage points need to be able to impact large sections of a system in order to be effective
2	Purpose: The perpetuation of racial inequality in communities	Student demonstrates awareness that systems can manifest purposes that are unintended by human actors in the system
13	Feedback loop: <i>If investments (by individuals, the government or the industry) increase, the economy is going to grow. As a consequence, more funds are available to individuals, the government and the industry, to invest more, which intensifies economic growth, leading to even more funds available to invest</i>	Student demonstrates awareness that a feedback loop must feedback, it is not a linear relationship

Following the completion of the individual systems map, students collaborated with their group members for their community partner project to develop a unified systems map. Figure 5 is an example team map.



Figure 5. Team Constructed Systems Map Examining Racism in a Rural Environment

The numbers on the map describe the specific interconnections between the elements. Sample interconnections include:

- 1. Social media displays/hosts racial behaviours
- 7. Informational resources improve EDI educational Workshops
- 10. EDI educational workshops bring awareness to Mental Health Adversities

Comparing the individual and team maps revealed improved understanding of the examined system. This occurred through the inclusion of additional perspectives, increased awareness of individual biases, and negotiation of what to include in the team map. These factors were described by students in all seven teams. For example, Student 28 stated:

Throughout the course, I discovered that connecting with others in the course contributed to meaningful learning...I learned more about the different interdisciplinary approaches, elements, and ideas related to the issue or problem faced by [the organization]; this contributed to my development and learning process greatly... Because the group was diverse and knowledgeable in our own areas, it helped me to envision sustainability from many different lenses overall.

Another common statement was the need to understand the logic or rationale behind individual choices before they could agree on a common map. This corresponds to research regarding the impact of peer learning. In peer learning, students share knowledge, ideas, and experience in a

non-hierarchical relationship (Boud, 2001). Peer learning within the project groups cannot be separated from the impacts of project-based and community-engaged learning in the current study. The process of working together supported groups in defining the boundaries of the system, which is described by Evans (2019, p. 5533) as a key skill for systems competence.

From the instructor's perspective, having students negotiate the systems map demonstrates both interpersonal and systems thinking competence. Successful groups explain the assumptions underlying their individual maps and then negotiate the group map. While students often start their individual maps by identifying the elements (the circles in the two examples above), they find this process doesn't work when moving to the collaborative map because they realize how many assumptions and decisions underlie their elements that they were not aware of at the time of construction. Through this process, the students develop many of the systems related knowledges and skills that Evans (2019, p. 5533) identified including "understanding issues of scale and complexity", "understanding that systems are constructs and that different people may delineate and describe systems differently", and reflexivity. Similarly, Wiek *et al.* (2011, p. 207) state that systems thinking competence includes "comprehending, empirically verifying, and articulating [system] structure, key components, and dynamics". Further, within interpersonal competence students developed effective group discussion techniques, conveyed insights, and practiced active and deep listening (Evans, 2019). This was done to engage in problem solving as they developed a common systems map.

Anticipatory

Anticipatory competence is the most difficult competency to tie specifically to the community engaged learning opportunity in the course, although it was significant for the course overall (W=168, p < 0.00171). All students who mentioned anticipatory thinking as their most important takeaway (five of 28 students) referred to the reading "Other worlds are possible" (Weston, 2012). This chapter introduces requirements for sustainability that encourage anticipatory thinking, including believing that changing the system is possible (pp. 13-17), that new scales are required to measure good done rather than harm not done (pp. 17-21), and that sustainability, must be celebrated (pp. 24-28). As in all case study research, the contextual conditions of the case can't be separated (Yin, 2018). Therefore, it is possible that this reading, rather than the project-based, community-engaged learning, was the largest contributor to anticipatory competence amongst students. This will require further research to investigate.

The restrictions of a semester-based course potentially hindered the development of anticipatory thinking within the community-engaged learning projects. Community partners were asked to identify potential projects for students as part of their initial submission of interest. As a result, the students were less engaged in anticipating or envisioning future states. However, the process of brainstorming different ideas for their projects and weighing the challenges and opportunities of each option before proposing the final direction for the project is evidence of anticipatory thinking. Therefore, while the projects themselves may not be clearly connected to the development of anticipatory thinking, students did acknowledge this process through statements such as the following from participant 10.

Another way that developing sustainability competencies contributes to my future ability to take on sustainability projects is that I am able to work with a group to collectively create a sustainable vision for a project. By doing so, I know now how to work together to look at many different options to figure out which one is more sustainable. I can look at these different opinions and ideas from people and help to critically think about a direction to go.

Normative

Normative competence was not mentioned by any of the students as a key takeaway from the course and yet it showed a high level of significance in the self-assessment (W=153, p < 0.00015). Both statements in the self-assessment directly connect to the course pedagogies: "I am able to compare and contrast several alternatives for a project" and "I am able to collectively create and craft sustainability visions for a project". It is possible that this latter statement was reflected in the impact of interpersonal skills that many students did comment on, while the former may have been connected to anticipatory thinking by students. This again illustrates the difficulty of disentangling the different competencies (Redman and Wiek, 2021).

The process engaging with the normative competence within the context of the communityengaged learning projects was two-fold: First, the students, through the process of systems mapping identified, reconciled, and negotiated their individual perspectives on the current system. Second, they negotiated with the community partner to take the values, principles, goals, and targets of the partner and their stakeholders or participants into account. For example, industry stakeholders within the air quality monitoring organizations had to be considered during project development. For example, one of the Twitter posts the group developed focused on SDG 8: Decent Work and Economic Growth. In the thread they describe how air quality impacts many factors like well-being and agriculture that will impact economic growth (Alberta Capital Airshed, 2021).

The group working with an anti-racism organization in a rural context included text that demonstrated normative competence throughout their project. For example, at the start of one activity in the anti-racism activity kit they developed, they stated "There are no wrong answers in this game. It is about exploration and keeping an open mind. Some of the questions might feel uncomfortable, but they are there to encourage learning." This illustrates awareness of the current state of these discussions, but still encourages the importance of having the discussion.

Strategic

Strategic competence had the lowest significance of the five competencies. Two statements were attributed to this competence: "I am able to learn new skills and connect them to my professional goals/plans" and "I am able to see real world situations and relationships". Although we did not analyze these two items separately due to the small sample size, the difference in the pre and post assessment means for these two items is quite variable. For the former item, the mean on the pre-assessment was 4.5, while the post assessment was 4.65. The latter statement had a larger change in mean from 4.15 (pre) to 4.65 (post). This may be explained because the students

are likely pursuing undergraduate education with the goal of learning new skills and connecting them to their professional goals and plans (Nadelson *et al.*, 2013). As a result, this experience was not unique to this course.

Several of the projects were specifically targeting strategic competence in that they provided guidance and research on how the community partner organizations could move towards greater sustainability. For example, one group conducted a literature review for an agricultural organization on strategies and practices to increase rates of soil carbon storage. They also included a cost-benefit analysis to support farmers in incorporating sustainable practices. Another group examined and created a guidebook for an organization looking to improve waste diversion rates at large scale events. They broke their recommendations down into immediate, ongoing, and long-term categories to facilitate both immediate action and future goal setting. These examples illustrate that students demonstrated strategic competence within their projects.

Community Partner Feedback on Competency

The partners were not introduced to the five key sustainability competencies. As a result, the community partners who provided feedback (two of six accounting for three projects) provided general feedback relating to what sustainability related skills, activities, or competencies they witnessed. Both partners that provided feedback mentioned research and communication, in addition collaboration and planning were mentioned once each. These skills all fall within what Redman and Wiek (2021) identify as general and professional competencies because they are used in many different fields. In other words, they do not apply to sustainability more than other areas. However, with the small sample size, it is difficult to draw conclusions regarding these observations.

Community Partner Projects and the SDGs

Sustainability encompasses multiple domains including economics, environment, social justice, and cultural vitality. However, it is often viewed through a much narrower lens (Fisher and McAdams, 2015). The SDGs, when taken together, illustrate the broad requirements of sustainability (Leal Filho *et al.*, 2019). The instructor, with support from the Careers and Experience office at the host institution, used the UN Sustainable Development Goals to convey the broader understanding of sustainability to potential community partners. While all community partner projects were related to at least one SDG, the integration of the SDGs ranged from direct to indirect as shown in Table 6.

Project Description	Connection to SDGs
Social media posts (Twitter and Instagram)	Direct: focused on educating organization
highlighting the relationship between	followers on both air quality and the SDGs.
different SDGs and air quality	Covered multiple SDGs

Table 6. Project Descriptions and SDG Connections

Brochure highlighting the relationship between different SDGs and air quality	Direct: focused on educating organization followers on both air quality and the SDGs. Covered multiple SDGs
Anti-racism kit including activities and resources to support anti-racism education and ongoing engagement within rural communities that are predominantly white	Indirect: The SDGs are not mentioned within the project; however, students considered the following goals: SDG 4: Quality Education; SDG 10: Reduced Inequalities; and SDG 17: Partnership for the Goals.
Video for community employers about the benefits of adult literacy programs in supporting worker engagement, productivity, and skills building	Indirect: focus is on how access to adult literacy programs improves equal access to SDG 4: Quality Education. The project also indirectly impacts SDG 8: Decent work and economic growth and SDG 10: Reduced Inequalities.
Research report on agricultural methods to increase carbon sequestration in soils	Direct: carbon sequestration and agricultural practices are essential to multiple SDGs: Goal 2: Zero hunger; Goal 3: Good health and well- being; Goal 12: Responsible consumption and production; Goal 13: Climate action; and Goal 15: Life on land.
Research report on waste management at major events: Strategies to increase waste diversion	Direct: specific strategies for waste reduction target Goal 12: Responsible consumption and production.
Research report on best practices in social procurement policies	Direct: social procurement practices are connected to SDG 12: Responsible consumption and production and indirectly to SDG 8: Decent work and economic growth and SDG 13: Climate change.

At first, the SDGs were identified as a kind of shorthand to engage the breadth of community partners that the course required. However, it turned out to have a more significant impact. One of the community partners that provided feedback indicated that the project made their contribution to the goals more overt and concrete. Given that there is still limited awareness of the SDGs (United Nations Secretary-General, 2019), this demonstrates that community-engaged learning projects have the potential to contribute to awareness and possibly action on the goals.

Similarly, the second organization, which supervised two different projects, indicated that the projects contributed to not just their awareness of student groups to support their own engagement with the SDGs through research, but they also identified that the organization itself can become a resource for their community in increasing engagement in the SDGs.

Additionally, two student projects focused on public awareness through communication of the relationship between the SDGs and air quality. While not quite the same approach, Manolis and Manoli (2021) found that awareness of the SDGs increased when student groups researched ecological projects that related to the SDGs and presented them within the capital city of the region at a sustainability related event.

The shaping of the call around the SDGs did support the engagement of a range of potential projects across all four domains of sustainability. However, additional research is required to determine the extent of the impact of the call on the community partners' future engagement with the SDGs.

Limitations

A case study approach is used when it is not possible to separate the goal of the study from the contextual factors of the case. This limits the generalizability of the research. However, the results support the use of project-based and community-based learning opportunities to contribute to the development of sustainability competencies. Small sample sizes also impact the generalizability of the research. However, as an exploratory case, this study supports future use and investigation of the SDGs as a framework for engaging community partners with sustainability education. It also supports the role of community-engaged learning to support increased engagement with the SDGs among community organizations. Finally, the inclusion of the three emerging competencies suggested in Brundiers *et al.* 2021 is an important element that needs to be investigated to determine the applicability of the pedagogical approaches used here in supporting development.

Implications

The results of the pre and post self-assessment combined with the instructor assessment in this case study generally supports the effectiveness of project-based, community-engaged pedagogical approaches to developing sustainability competencies. However, our results comparing student self-assessment of their learning on the different competencies, shows some variance from past findings. Trencher *et al.* (2018) report that all programs they looked at were less effective at developing anticipatory competence vs. other key sustainability competences, while practice-oriented programs were better at developing normative, strategic, and interpersonal competencies (p. 839-840). In this study, we also found that normative and interpersonal competencies were well developed but anticipatory or future-thinking competence was reported as being more substantially developed compared to strategic competence. Discussion of the results of self-assessment of anticipatory competence points to the contributions of a course reading. This provides some support for augmenting or balancing hands-on project/problem based and community-engaged learning with other forms of academic learning.

Given the lack of awareness generally of the SDGs (UN Secretary-General, 2019) and the common narrow understanding of sustainability (Fisher and McAdams, 2015), we have demonstrated that using the SDGs to frame project-based, community-engaged learning can

contribute to greater awareness of the SDGs and the values that they encapsulate for students and community partners.

This case study adds to the literature around preparing students to be sustainability practitioners vs. researchers (Trencher *et al.*, 2018). The professional sustainability environment is likely as important to creating change as education that creates change makers. Cörvers *et al.* (2016, p. 352) found that sustainability professionals at the time were mainly focused on "climate change and energy issues". This professional focus has likely broadened and changed, so their views of important skills may have as well. Including sustainability professional's perspectives in analysis of future case studies in academia will also contribute information relevant to the implementation competency suggested by Brundiers *et al.* (2021, p. 21).

One future focus of research could be to reconnect with past students who have developed sustainability competencies through formal learning opportunities and assess how the competencies have contributed to their professional work. This would support the call made by Redman and Wiek (2021, p. 8) to test the sustainability competency framework "in real-world problem-solving settings".

Originality

This case study represents a unique context of an interdisciplinary undergraduate course on sustainability that incorporates a diverse mix of teaching, learning, and assessment pedagogies. Konrad *et al.* (2021, p. 536) identify a need for studies investigating the many influences on students in their learning, including their learning processes. In this case, the pedagogy and the assessment strategy were part of the student's learning process.

This study incorporates the SDGs not just as content to be learned by students, or in connection with the key sustainability competencies, but as a tool for selecting and educating community partners. This approach or information reporting on the effect of using this approach with community partners has not been found by the authors to be well represented in the literature on sustainability education.

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The Effect of Different Instructional Methods and Beliefs Towards Mental Computations

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Abstract

The purpose of this research are threefold: 1) to compare the outcomes of preservice teachers' mental computation performance of whole numbers, integers, and rational numbers, using the three different instructional approaches (i.e., direct teaching, open approach, and control group), 2) to identify which operations showed a marked difference on the Mental Computation Test (MCT) performance for each group, and 3) to measure the changes in positivity or negativity of belief towards learning written and mental computations after an intervention. PTs in the K-8 Teacher Education Program participated in this study. A mixed research method is used for this study. Specifically, a quasi-experimental design is employed using a pre-and post-MCT that consists of 69 items in relation to whole numbers, integers, and rational numbers (i.e., fractions, decimals, and percents). A one-way analysis of covariance is used to reveal if there is a statistically significant difference in post-MCT scores. In addition, the Mathematics Attitudes Survey (MAS) is designed to analyze preservice teachers' positivity or negativity of belief regarding their mental computation and written computation learning. This study aims to contribute to the existing body of research that provides useful insights for mathematics educators on how to effectively apply instructional approaches to promote diverse students' mathematics knowledge of mental computations and to provide useful information as a measure of current preservice teachers' mental computation ability and beliefs on mental computation.

Keywords: Mental computations, direct teaching, open approach, preservice teachers, attitudes towards learning mental computations

Introduction

Today, more studies pay attention to the success using mental computation and try to determine its influences on students' achievement in and out of school (Yang & Huang, 2014); however, the main focus of mathematical computation in the primary school has been placed on written pencil and paper algorithms. Since many classroom teachers have been educated in ways that focus on the rote memorization of basic facts, and the development of procedures for completion of traditional written algorithms, their teaching strategies are accordingly influenced by their previous learning experiences. Although these teachers can see benefits for using mental computation strategies in their classrooms, their lack of related knowledge has led to a lack of confidence and teaching skills (Hartnett, 2007). It is even more doubtful how effectively the preservice teachers use the strategies they have developed. To succeed in learning and in teaching mental computation to students, it is important for preservice teachers to be prepared to teach effectively prior to classroom teaching.

There are two growing different instructions: direct teaching and developing students' own strategies (Hartnett, 2007; Varao & Farran, 2007). Even though the direct teaching instruction originally came from a behavioristic approach, many researchers agree that the direct teaching should be involved in students' conceptual understanding along with their procedural skills (Reys, Reys, Nohda, & Emori, 1995; McIntosh, Nohda, Reys, and Reys, 1995). The second approach, developing students' own strategies, comes from a constructivist view (Becker & Epstein, 2007; Hartnett, 2007; Becker & Shimada, 1997). Teachers can create this environment by encouraging students to solve problems in a variety of ways (Becker & Epstein, 2007; Hartnett, 2007). Using the *open approach* with constructivist instructional benefits to deepen students' mathematics understanding and content knowledge. *Open approach* problems are those for which there are multiple correct answers or ways of solving the problems. The results of the *open approach* showed that students have an opportunity to be more actively involved in lessons, to deepen their mathematics learning, and to enjoy their experiences in problem-solving (Becker & Epstein, 2007).

With respect to teaching practice, Jong and Hodges (2015) investigated the attitudes towards mathematics among preservice elementary teachers in relation to their experiences with K-12 learners of mathematics and experiences in a teacher education program. The result showed that developing positive attitudes was an important aspect of teacher education as attitudes influence the instructional practices preservice teachers use with students.

Thus, this study is closely connected to the Sustainable Development Goal 4 (SDG 4), Target 4.1, *by 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes.* This means that mental computation skills can be used as an essential key concept for developing both preservice teachers and their future students' mathematics proficiency and understanding.

Purpose and Research Questions

The purpose of the current study is twofold. The first part of the study seeks to compare the outcomes of preservice teachers' performance in mental computation of whole numbers, integers, and rational numbers using the three different instructional approaches (i.e., direct teaching, open approach, and control group) and to identify which operations showed a marked difference on the Mental Computation Test (MCT) performance for each group. The second part measures the changes in positivity or negativity of belief towards learning written and mental computations after an intervention using the two approaches (i.e., the direct teaching approach and the open approach). The specific research questions that guided this study were as follows:

- 1. Are there any significant differences in mental computation performance between the experimental groups (i.e., *Direct Teaching* and *Open Approach*) and the control group before and after instruction?
- 2. Which mathematical operations showed a marked difference in improvement of pre- and post-MCT performance among the three instructional approaches?

3. How do the preservice teachers' mathematical beliefs towards written and mental computation change after the intervention?

Methodology

This study used a quasi-experimental, non-equivalent control group design. The convenient sampling design was used.

Participants

The population is a group of preservice teachers enrolled in a K-8 teacher education program at a mid-sized, four-year, state university in the USA. The convenient sampling design was used for this study. The sample size was 50 preservice teachers before the intervention and 40 after the intervention. Ten students were dropped out during the semester. Three classes were used for this study: two classes experimental groups enrolled in Course A, and one control group. Course A is the first required class, which provides an overview of a real number system, operations on whole numbers, arithmetical skills using mathematical activities and mathematical thinking, and problems solving skills. In terms of mathematics attitudinal surveys (MAS), 27 of the 50 participants received the intervention. 20 participants from the control group did not take part in the post-MAS because no intervention was provided for them. 3 participants were dropped during the intervention.

Test Instrument

The researcher designed and constructed the Mental Computation Test (MCT) to determine whether there were significant changes in preservice teachers' mental computation performance. A pilot study was conducted in the previous semester. After the piloting of the instrument, we identified weaknesses in the structure of the MCT and revised the test. The MCT included 69 problems in relation to whole numbers, integers, and rational numbers (i.e. fractions, decimals, and percents). The MCT was administered using PowerPoint slides. The questions were displayed one at a time on PPT slides for about 30 seconds. Each item of the MCT was assigned one point for a correct answer and no point for an incorrect answer or no response. The reliability of the MCT items was calculated using Cronbach's alpha coefficient ($\alpha = 0.96$). Three mathematics educators ascertained the content validity of the test.

The researcher designed the Mathematics Attitudes Survey (MAS). The content and face validity of MAS was reviewed by three mathematics educators and pilot tested. The necessary items for each operation were modified, deleted or added. Descriptive statistics were utilized to analyze the results. The Likert-type scale consisted of 30 items and clustered by the following two categories: preservice teachers' perception about mental and written computation (16) and PTS' perception of instruction between written and mental computation (14). Two types of statements were included in a parallel way – each statement was accompanied by a parallel statement. Cronbach's alpha test was calculated to check the internal consistency reliability (30 items: α = 0.83).

Procedure for Intervention

For the first session, the pre-MCT and pre-MAS were administrated. The researcher carried out the intervention sessions (i.e., 11 sessions over 8 weeks) for the whole numbers, integers, and rational numbers during the semester. As for the first session, the participants completed pre-MAS. After that, in the two experimental groups, the MC strategies that were more focused on conceptual understanding were respectively implemented using the following two instructional methods: the direct teaching and the open approach. As for the direct teaching, the researcher introduced and demonstrated several MC strategies in the lessons using more flexible deductive strategies such as compensation (e.g., 20 × 199 = 20 × (200 – 1) = 20 × 200 – 20 × 1 = 4,000 – 20 = 3,980), dividing using factors (e.g., $70 \div 14 = (70 \div 7) \div 2 = 5$), number facts (e.g., $9\% \times 450$ = 10% of 450 - 1% of 450 = 45 - 4.5 = 40.5), and so on. For the open approach group, an openended problem was first presented progressing from easy to more complicated. The participants were asked to find solutions in many ways using their own natural thinking abilities. Then, selected PTs shared or explained how they solved their problems on the board for the whole class to see. Then we discussed what solutions were the most appropriate for a given problem. No intervention is provided for the control group. In the last session, preservice teachers were given both post-MCT and post-MAS.

Analyzing Data

To examine differences in mental computation performance between the three groups before and after instruction, and to examine a marked difference for each operation with different groups, a one-way ANOVA was conducted to determine whether there was a significant difference in the mean pre-MCT scores. An Analysis of Covariance (ANCOVA) was conducted on post-MCT performance, with the type of instruction (i.e. direct teaching, open approach, and Control) and pre-MCT scores as covariates to control for pre-MCT score differences among the groups. Descriptive and inferential statistics were used to analyze the results of the Mathematics Attitude Survey (MAS).

Findings

Differences Between Pre-and Post-Mental Computation Test Performance

With respect to inferential statistics, a one-way analysis of covariance (ANCOVA) was conducted for this study. Levene's test and normality checks were carried out and the assumptions of normality and homogeneity of variance were met. The result of the Levene's test showed the variances are not unequal, F(2, 38) = 0.207, p = 0.814.

Table 1

Overall descriptive statistics comparison between experimental groups and the control group on the pre-and post-mental computation test.

TEST	Direct Teaching			Оре	Open Approach			Control		
	Ν	М	SD	Ν	М	SD	Ν	М	SD	
Pre-MCT	14	27.86	14.57	16	32.38	16.05	20	35.80	14.21	
Post-MCT	11	40.08	14.00	15	44.60	18.82	14	34.21	14.44	
Improvement	11	9.50	5.58	15	11.87	6.85	14	-3.27	7.62	

Table 2 summarizes the one-way ANCOVA result for the post-MCT by instructional condition and pre-MCT scores. There was a statistically significant difference F (2, 37) = 17.52, p < .05, at the .05 level, in post-MCT scores between the different instructional groups, when adjusted for pre-MCT scores. Accordingly, both the observed and adjusted means showed that although the open approach group performed better than the direct teaching group, the means of both groups have increased with a similar amount (i.e., M= 9.5 vs M= 11.87) since the PTs in the open approach group started off higher. The PTs in the control group performed the worst.

Table 2

Type Groups	of	Mathen	Mathematics Scores							
		Observ	ed	Adjuste	ed	<u>en</u>	5			
		Mean		Mean		3D	[]			
Direct		40.09		12 70		14.00	10			
Teaching		40.00		42.79		14.00	12			
Open		44 60		45 20		10 01	15			
Approach		44.00		40.29		10.01	15			
Control		34.21		31.16		13.50	14			
Source	S	SS	df		MS	F				
Pre-MCT	7	7825.58	1		7825.58	3 17	4.50*			
Instruction	1	570.92	2		785.46	17	.52*			
Error	1	659.29	37		44.85					

ANCOVA results and descriptive statistics for post-MCT.

Note. R² = .84, Adj. R² = .83, adjustments based on Pre-MCT mean = 39.75. Homogeneity of regression tested and not significant: F = 1.40, p>.05. Pre-MCT regression coefficient = 0.88*. * p < .05

As indicated by Table 3, multiple comparisons showed that there was a significant difference between the direct teaching and control groups (p < 0.05) and the open approach and control (p < 0.05) groups. However, these two groups did not significantly differ on their post-MCT scores.

Table 3

Multiple comparisons and mean differences in post-MCT scores by instruction type controlling for pre-MCT scores.

Comparison	Mean Difference	Standard Error of Difference	Bonferroni Adjusted (95% CI)
Direct teaching vs Open approach	2.49	2.60	-9.01, 4.02
Direct teaching vs control	. 11.64*	2.67	4.94, 18.33
Open approach vs. control	า 14.13*	2.51	7.85, 20.41

Note. Comparisons based upon ANCOVA adjusted means controlling for Pre-MCT mean scores of 39.75. * p <.05, where p-values are adjusted using the Bonferroni method.

Operations that Showed a Marked Difference

Table 4 summarizes the comparison of three different groups with different instructions for each operation between pre-and post-MCT scores. There were significant differences between preand post-MCT performance among the three groups in solving multiplication, fraction, and decimal operations. More specifically, the one-way ANCOVA for mental multiplication performance was significant, F (2, 23) = 8.48, p = .002, η_p^2 = 0.43. The effect size (η_p^2) = 0.43 is quite large. The pairwise comparisons indicated that there was a significant difference between the open approach and control groups (p = 0.006). Additionally, the ANCOVA for decimals, F (2, 26) = 5.88, p = .008, η_p^2 = 0.31 showed a significant result and large effect size. The pairwise comparisons showed that there were significant differences between the direct teaching and control groups (p = 0.026) and between the open approach and control groups (p = 0.023). A significant difference between the experimental groups was not present for the pairwise comparisons.

Table 4

Comparison of type of instruction for the operation between pre-and post-MCT scores.

Operation	# :to:	of	Test	Direct T	eaching	Open	Approach	Contr	ol	F	$\eta_{ ho}{}^2$	p
	ne	m	(%)	М	SD	М	SD	M SE)			
Subtraction	s	5	Pre	61.60	29.59	65.20	20.07	76.00	12.94	2.57	.32	.235

		Post	80.00	19.22	73.40	8.17	65.60	26.71			
Multiplications	9	Pre	15.00	19.40	18.78	21.27	23.89	21.33	8.48 *	.43	.002
		Post	38.89	25.97	39.33	17.44	22.11	13.68			
Integers	2	Pre	36.00	9.90	56.50	9.19	42.50	10.61	.80	.44	.556
		Post	45.50	17.68	63.00	14.14	46.50	14.85			
Fractions	8	Pre	28.63	14.43	45.50	20.07	41.88	15.80	4.66 *	.32	.022
		Post	46.75	17.38	65.75	14.00	39.25	19.03			
Decimals	10	Pre	48.00	23.36	56.30	25.11	57.00	19.18	5.88 *	.31	.008
		Post	67.50	18.63	76.80	13.05	52.90	22.42			
Percents	6	Pre	26.00	24.62	28.33	32.10	35.00	28.28	.98	.40	.401
		Post	32.00	27.66	45.50	20.71	32.00	24.24			

Note. η_p^2 = Partial Eta-Squared. * p < .05

Mean Changes in Attitudes towards Mental and Written Computations

Changes in the mean score of attitudes can be examined visually as indicated by Table 5. As for the pre-MAS, the minimum score was 71, with a maximum score of 129, out of a possible 150, indicating a rather wide range of attitudes at the beginning of the course. The mean pre-MAS score was 103.24 (SD =10.11). On the post-MAS, the minimum score was 70 and the maximum score was 115, indicating a narrower range of attitudes at the end of the course. The mean score for the post-MAS was 104.85 (SD = 9.29). Although the total standard deviation between mental and computation showed not much difference, the difference towards written computation between pre-and post-MAS showed a wide range of scores on attitudes. It could be interpreted that preservice teachers' attitudes towards written computations were changed.

Table 5

Descriptive Data for Differences towards Mental and Written Computations.

		Minimum Raw Score	Maximum Raw Score	Mean*	Standard* Deviation	Ν
Pre-MAS	Total Mental	71 32	129 71	103.24 54.78	10.11 6.84	30

	Written	32	60	48.46	5.44	
Post-MAS	Total	70	115	104.85	9.29	27
	Mental	33	74	58.70	8.70	
	Written	20	56	46.15	9.17	

Note. MAS: Mathematics Attitudinal Survey, * Rounded to nearest hundredth

Tables 6 and 7 show the mean score changes of the two experimental groups. The positive changes are mostly related to written computation. The greatest positive mean change between pre and post was 0.44: "I believe WC is more useful in real life situations." This was followed with: "I have spent more time in school doing written computation than mental computation." (Mean Changes (MC) = 0.40); and "I am confident with learning and teaching written computation (MC = 0.39). The negative changes were mostly connected to the mental computation. There were two negative changes that were greater than 0.25. First, "I believe MC is more useful in real life situations" decreased with a mean change of 0.34 between the pre and post surveys. Second, with a negative mean change of 0.33 was: "Mental computation should be taught during the school years."

Table 6

Mean Changes in belief towards Mental and Written Computations.

	Pre-MAS			Pc	st-MAS	Me Ch	Mean Change	
	Ν	Mea	SD	Ν	Mea	SD		
		n			n			
1. I have learned WC strategies during my	3	3.93	0.7	2	3.93	0.92	-0.01	
school years.	0		4	7				
2. I have learned MC strategies during my	3	3.50	0.8	2	3.41	1.05	-0.09	
school years.	0		6	7				
3. I have spent more time in school doing	3	3.90	0.9	2	4.30	0.78	0.40	
WC than MC.	0		6	7				
4. I have spent more time in school doing	3	2.13	0.9	2	2.15	0.82	0.31	
MC than WC.	0		0	7				
5. I feel comfortable and safe when using	3	3.83	1.1	2	4.15	0.86	0.31	
WC.	0		2	7				
6. I feel comfortable and safe when using	3	2.77	0.9	2	2.74	0.98	-0.03	
MC.	0		7	7				
7. I am confident with learning and	3	3.87	0.9	2	4.26	0.71	0.39	
teaching WC.	0		4	7				
8. I am confident with learning and	3	2.87	1.0	2	3.04	1.13	0.17	
teaching MC.	0		4	7				
*9. I have used WC more than MC.	3	4.03	0.8	2	4.33	0.78	0.30	
	0		9	7				

10. I have used MC more than WC.	3 0	2.07	0.7 8	2 7	2.11	0.97	0.04
11. I believe WC is more useful in real life	3	2.93	0.9	2	3.37	1.11	0.44
situations.	0		1	7			
12. I believe MC is more useful in real life	3	3.57	0.8	2	3.22	0.89	-0.34
situations.	0		2	7			
13. WC should be taught during the	3	4.10	0.7	2	4.26	0.71	0.16
school years.	0		1	7			
14. MC should be taught during the	3	4.03	0.7	2	3.70	1.10	-0.33
school years.	0		2	7			
15. WC is easy to learn and solves	3	3.73	0.8	2	3.93	0.73	0.19
problem quickly.	0		7	7			
16. MC is easy to learn and solves	3	3.30	0.7	2	3.15	1.20	-0.15
problems quickly.	0		9	7			

Note. WC: Written Computation; MC: Mental Computation

There were also negative and positive changes between the pre- and post- surveys on instruction in mental and written computations as shown in Table 7. The positive changes were mostly found in written computation: "Written computation should be introduced first when teaching mathematics" (MC = 0.34). There were also positive increases indicating that "I think I will use WC more when I teach students (MC = 0.32)". Also, survey results showed that "students who are highly skilled in WC develop problem-solving skills (MC = 0.25)." The surveys' negative changes mostly related to the MC. The greatest negative change in means between pre and post was - 0.21: "Students can be successful mathematics learners by teaching only MC." This was followed with: "I think I will use MC more when I teach students" (MC = -0.11) and "Mental computation should be introduced first when teaching mathematics" (MC = -0.10).

Table 7

Mean Changes in Instruction towards Mental and Written Computation.

	Pre-M	AS	Post-MAS				Mean	
-	Ν	Mean	SD	Ν	Mean	SD	Change	
17. I think I will use WC more when I teach students.	30	3.53	0.82	27	3.85	0.91	0.32	
18. I think I will use MC more when I teach students.	30	2.97	0.85	27	2.85	1.06	-0.11	
*19. Students can be successful mathematics learners by teaching only WC.	30	2.48	0.78	27	2.70	1.10	0.22	

20. Students can be successful mathematics learners by teaching only	30	2.43	0.73	27	2.22	0.75	-0.21
MC.							
21. WC should be introduced first when	30	3.73	0.91	27	4.07	0.87	0.34
teaching mathematics.							
22. MC should be introduced first when	30	2.80	1.00	27	2.70	1.17	-0.10
teaching mathematics.							
*23. Teaching WC can build students'	30	4.00	0.53	27	4.22	0.42	0.22
mathematical procedural knowledge and							
understanding.							
24. Teaching MC can build students'	30	3.70	0.84	27	3.70	0.91	0.00
mathematics procedural knowledge and							
understanding.							
25. WC should be taught to learn	30	3.73	0.83	27	3.96	0.90	0.23
advanced mathematics.							
26. MC should be taught to learn advanced	30	3.40	0.89	27	3.33	1.00	-0.07
mathematics.							
27. Students can develop their natural	30	3.73	0.74	27	3.81	0.74	0.08
thinking ability through learning WC.							
28. Students can develop their natural	30	3.83	0.59	27	3.78	0.89	-0.06
thinking ability through learning MC.							
29. Students who are highly skilled in WC	30	3.60	0.77	27	3.85	0.77	0.25
develop problem solving skills.							
30. Students who are highly skilled in MC	30	3.60	0.77	27	3.74	0.66	0.14
develop problem solving skills.							

Note. WC: Written Computation; MC: Mental Computation

Research Limitations and Implications

The major findings of this study as explicit partial answers to the three research questions are briefly summarized as follows. When examining preservice teachers' differences in mental computation performance between the experimental groups and the control group, experimental groups (i.e., open approach and direct teaching) performed better than the control group. The level of improvement in the post-MCT scores of the direct and open approach groups was not significantly different. When comparing the performance of experimental groups, the open approach group performed better than the direct teaching group. However, this study found that direct teaching instruction involving students' conceptual understanding may be equally effective in improving preservice teachers' performance of MCT as the open approach.

There were significant differences between pre-and post-MCT performance among the three groups in computing whole number multiplication, operations with fractions, and decimal operations (See Table 4). Specifically, studies found that learning fractions and decimals are difficult for students to master (Bailey et al., 2012; Hiebert and Wearne, 1985; Lortie-Forgues el

al., 2015; Siegler et al., 2011). It is important results because mental computation using direct teaching or open approach can build students' ability to compute fraction and decimal operations.

As for the mean changes in preservice teachers' beliefs towards mental and written computation, there were negative and positive changes. The positive changes mostly related to written computation, while the negative changes were mostly connected to mental computation. Similar results of the pre-and post-MAS on instruction regarding mental and written computation were found. The positive changes were mostly related to written computation, while negative changes were mostly related to written computation, while negative changes were mostly related to written computation, while negative changes were mostly connected to mental computation. Interestingly, this study revealed that before the intervention, participants were well-aware of the importance of learning mental computation and they believe that both written and mental computations should be taught during the school years; however, after intervention, the levels of beliefs towards learning mental computation was decreased and participants put more emphasis on using written computation. This may be due to their lack of mental computation skills, so this leads to relying more heavily on written computation because it is still more familiar to them.

Five implications for future study are as follows. First, more empirical studies comparing the effect of direct teaching and open approach instructions are needed. Several studies (Becker and Epstein, 2007; Kwon et al., 2006; Lin et al., 2013) found that open approach instruction results in significant learning gains in comparison to traditional instruction; however, for this study, the results of the open approach group performance did not show any significant increases in MCT performance compared to the direct teaching group. This is an interesting finding because during the intervention, the researcher observed PTs' active participation and a variety of solution methods that cultivate students' flexibility and creativity. A possible explanation for these results may be the lack of adequate time and test anxiety.

Second, Kirschner et al. (2006) assert that direct instruction is needed for low-achieving students and *unguided instruction* (i.e., open approach) is effective for more able learners. The findings of this study would be different if the researchers conducted this study based on students' different levels of achievements. Further studies, which take these variables into account, need to be undertaken.

Third, it will be necessary for researchers to conduct power analyses to determine minimum sample sizes for studies. Three operations that indicated non-significant results (See Table 4) showed larger effect size (i.e., subtraction ($\eta p^2 = 0.32$), integers ($\eta p^2 = 0.44$), and percents ($\eta p^2 = 0.40$)) although non-significant results were shown. Thus, it could be interpreted that non-significant results may be due to lack of power rather than lack of effect.

Fourth, the findings of this study confirmed that preservice teachers were more likely to use written computation than mental computation when solving mathematics problems and revealed that they did not predict their success of future mental computation teaching due to a lack of mental computation knowledge and confidence. To have students consistently practice mental computation in their K-12 mathematics classrooms or to use mental computation skills in their real-life situation, it is imperative for mathematics educators and other mathematics stakeholders

to include mental computation in the U.S. K-12 mathematics curriculum, specifically, the mathematical content standards.

Last, mental computation is currently used in every culture by students (e.g., Reys et al., 1995, Yang and Huang, 2014), but few studies comparing preservice teachers' attitudes and beliefs on mental computation have been done across cultures. Therefore, a cross-cultural study of mental computation knowledge employed by the preservice teachers would be a productive implication for further study.

Limitations and Recommendations

The current research has several limitations. First, this study used a quasi-experimental, nonequivalent control group design. It is difficult to generalize the findings of the study because of the small sample size and a convenience sampling. Second, it is difficult to control for threats to internal and external validity of the study. Only 50 PTs in the pre-MCT and 40 PTs in the post-MCT participated in this study. Mortality or attrition is one of the potential threats to the internal validity of the study. Treatment diffusion (i.e. different treatment groups communicate with and learn from each other) is one of the potential threats to the external validity of the study. Third, only eleven intervention sessions were provided including test sessions and those were not enough time to practice mental computation strategies using multiple solution methods. Lastly, the validity of instruments such as pre-and post- MAS may not represent the actual construct because the researcher created the instrument. The evidence of instrumental validity was not thoroughly examined except for the content validity examined by three mathematics experts.

Originality/Value of the Paper

There is a lack of research comparing how these two alternative instructional approaches (i.e., direct teaching vs. open approach) impact the ability of preservice teachers' mental computation learning of whole numbers, integers, and rational number. Thus, this study aims to contribute to the existing body of research that provides useful insights for mathematics educators on how to effectively apply instructional approaches to them to be able to do mental computations. Also, preservice teachers' mathematics attitudes and beliefs towards written and mental computations have not been adequately studied and reported. Thus, this study may help mathematics educators in this regard.
Conclusion

To succeed in learning and in teaching mental computation to students, it is important for preservice teachers to be prepared to teach effectively prior to classroom teaching. Teachers' beliefs in mathematics teaching and learning may play a vital role in students' understanding of mental computation. The findings of this research will contribute to the research base that is related to preservice teachers' knowledge of mental computation. In other words, if the mental computation is an ability student should develop and improve, it should be analyzed what classroom instruction works best to encourage preservice teachers' mental computation ability. Viewing mental computation as higher-order thinking requires preservice teachers to learn their instructional techniques. Also, mathematics educators in preservice, inservice, and professional developmental programs may apply mental computations that work best for different learners. Finally, the findings of this study may provide useful information to mathematics teacher educators and educational policy makers, which may enhance existing teacher preparation programs and preservice teachers' attitudes toward mathematics teaching and learning. Therefore, this research help math educators ensure that by 2030, all girls and boys complete free, equitable, and quality primary and secondary education leading to relevant and effective learning outcomes, as indicated in Sustainable Development Goal 4 (SDG 4), Target 4.1.

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The First Phase of Development of Health Learning Package by Applying Technology-Based with Autonomous Learning Approach to Enhance Covid-19 Literacy and Health Behaviors as Lifelong Learning Skills

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Abstract

This paper demonstrated the first phase of Development of Health Learning Package by Applying Technology-Based with Autonomous Learning Approach to Enhance Covid-19 Literacy and Health Behaviors as Lifelong Learning Skills. Qualitative method was organized. Guideline questions for semi-structured interview as a research instrument were developed using content validate to constructed component of the Health Learning Package (HeL-pack). This paper presented the finding in part of the component including (1) the stated concept of Covid-19 literacy, (2) the manual for HeL-Pack including guidelines to practice autonomous learning, application of using technology, (3) pre-test for Health literacy (HL) and Health behavior (HB), (4) learning activities, (5) learning materials and (6) post- test for HL and HB.

Keywords: Health Learning Package; Health literacy; Health behavior; technological and autonomous learning approaches

Purpose and the Background

A huge number of COVID-19 cases have been increasingly surging due to the lack of efficient preventable or curable means. The lancet (2020) states that "there is numerous information toward covid-19, but there is also complex, contradictory, and false information." To contain this deadly disease, health literacy (HL) and health behavior (HB) toward covid-19 must be seriously educated to people. Consequently, effective educational approaches are needed to counteract the damaging effects of the infodemic, a massive amount of widely and rapidly circulating information about during COVID-19 crisis. This is as well as to increase empathy towards population groups at risk of stigmatization. To solve the problems, not only should public health educators must also attentively cooperate on this globally catastrophic challenge. Producing learning pathway to educated young people is one of the best ways to prevent Coronavirus disease (COVID-19), a communicable disease caused by the SARS-CoV-2 virus.

According to World Health Organization (2022) namely WHO states that the best way to prevent and slow down transmission is to be well informed about the disease and how the virus spreads. Protect yourself and others from infection should be concerned. Consider from the WHO weekly report during the end of March 2022, the number of new cases dropped again with a 14% decrease as compared to the middle of March. Many countries expect to declare the disease endemic, like many European countries, to promote tourism and economic recovery. However, the number of new weekly deaths has grown by 43%, this COVID-19 still called "Deadly Disease". That means the individual prevention should be educated and introduce for people to live with COVID-19 in our "Sustaining the Next Normal Living".

The purpose of this paper aimed to demonstrate the first phase of the development of Health Learning Package using Technology-based with Autonomous Learning Approach to enhance Covid-19 Literacy and health behaviors (HB) as lifelong learning skills (LLS) for year three undergraduate students studying in Health and Physical Education. The four-year preservice teacher education program in Thailand is required student to internship as a teacher training in a primary, secondary, or a high school for a semester (about 20 weeks or five month) by the Teachers Council. This Health Learning Package (HeL-pack) could benefit the Health Education Preservice Teachers to develop Covid-19 Literacy and HB as well as LLS. It is very important for Health education teacher to have those skills especially, the preservice teachers who would teach their students at school during their internship.

This HeL-pack is an innovative health education learning package that developing by applying technological and autonomous learning approaches. Technological learning is one of our new 21st century skills. Learners should be trained to use multimedia and digital tools (Scott & Cynthia, 2015; Facer, 2011; Facer & Sandford, 2010; Stehle and Peters-Burton, 2019). Moreover, the autonomous learning approach is the concept for lifelong learning and is not only using online skills but also onsite skills that could be practical. The main characteristics of autonomous learning are self-reports, diaries, evaluation sheets and persuasive communications as a means of altering learners' beliefs and attitudes (Benson ,2013). Those characteristics are needed to be practiced and trained before and during the process of learning with the teacher as a facilitator. This way students will not be isolated and must learn by themselves. The two approaches will be integrated to become new learning and teaching methods for the future educational system. These characteristics will promote learners as producers instead of transformers. According to Scott, Cynthia (2015), the new generation of digital tools is allowing students to become generators of content instead of passive consumers of knowledge, indicating a preference for active approaches to learning. The treatment will be developed as a smart learning package using research-based information. This HeL-pack also provides students to develop HL and LLS. According to Health People (2020); Chanuantong (2021). Hanemann & Robinson (2022) LLS extend the foundation for learning and working as the skills support students thinking, selfmanagement, and social interaction, empowering the pursuit of education and vocation goals. Lifelong learning needs not only literacy but also health literacy (HL) because people's wellbeing depending on being healthy and being healthy needs HL to access gualified health care information. The benefit of HeL-pack is a tool of learning that responsible consumption, and production (SDG 12 target 12.8) as all students and people can access health care information from at anytime and anywhere. It is also can promote lifelong learning prospects for all in the sustainable development goal 4 (SDG4). HeL-pack also helps them develop their awareness into health behaviors as well as students could apply HL for updating new information all the time of the ages. Therefore, this study can be considered as a Lifelong learning, sustainable development, and lifestyles in harmony with nature living.

Approach

Health education learning package (HeL-pack) is an innovative tool that integrates between technological and autonomous learning approaches. The two approaches can be applied as a new learning and teaching methods for the future educational system. These characteristics can promote lifelong learners as producers instead of transformers. According to Frey (2007); and Scott, Cynthia (2015), the new generation of digital tools is allowing learners to become generators of content instead of passive consumers of knowledge, indicating a preference for active approaches to learning. The treatment will be developed as a smart learning package using Technology and Autonomous learning approaches. The study aims to develop a learning package called HeL-Pack to enhance HL based on Covid-19 and HB.

Learning Package

Quebec Ministry of Education (2022) states that preschool, elementary and secondary education, teaching and learning must correspond to basic materials, which include teaching and learning task as well as learning packages. Learning package could be use as teaching material in classrooms or can be adapted as self-learning packages or Home-based learning material, depending on teacher designing and set the purpose of the lesson. The definition of learning package shall be analyzed from as a set of learning and teaching instrument to enhance learning ability which can be the course(s) and study programs and or related materials for learner support. tuition. (Ekapote, Usa, and Vijittra, 2021; Quebec Ministry of Education, 2022) The component of a learning package consists of learning tools, including a printed textbook (content), students and a printed or electronic teacher's guide, and evaluation activities. It may also include other electronic elements as learning and instruction VDO clips. The learning package is designed particularly for teaching and learning, and is considered a support, facilitation, and reference means. It intends to develop students' social perspectives and promote community values. It should promote learning experiences and present suggestions for developing cross-curricular competencies. The textbook and the teacher's guide should cover the complete program including learning outcome, content, learning activities, and assessment for a subject, or several subjects in the case of cross-curricular learning (Cassarino, 2003; Quebec Ministry of Education, 2022). The development of learning packages considers learners' needs and wants to design learning tasks, activities, and assessment that relate to the learning objectives as well as consider the cognitive processing of information among others (Cassarino, 2003). Additionally, to support learning, the development of the packages require that must be a shift from content-transfer to allows learners to reflect on their learning as well as to allows them to cooperate with each other (Singh et al, 2009; UNESCO, 2020). The recruiting criteria a learning package should be considered to ensuring the effectiveness for learners. Ministry of Education Quebec, 2022 suggests that the effective learning packages should; 1) be able to solve the learner's problem, 2) be directed to the solution of a health problem of major importance for the people, 3) make good a deficiency in the existing teaching system or in existing educational tools 4) not needlessly be superimposed on another package dealing with the same problem, 5) allow for the possibility of prompt updating when required, and 6)be more effective and economical than any other educational tool serving the same purpose. Moreover, the evaluation criteria of the leaning

package concerns with pedagogical aspects. The teaching and learning materials should be coherent with the requirements of the objective of the learning outcomes, learning process, and evaluation. Consequently, a learning package should include guidelines, application or media device, pre-test, learning process, learning materials and post- test

Technology-Learning approach can be used for managing learning process anywhere and at any time. This approach is very suitable in this Covid-19 spreading as can manage the leaning online from home. In addition, and mainly due to the learning curves introduced by technological skills development as sustainable learning tools. This can be considered as the advantages for teachers to promote learning to learn and learning how to use as well as practicing how to apply technology as the means of learning to learners to skillful for future skills. The Technology-Learning approach is included online learning, blended learning, flipped learning, hybrid learning, flexible learning, open learning, and distance education. These terms are often applied correspondently, but there may considerably differences in sense or key term of concept. For this study, the term "Technology-Learning approach" is defined as flexible learning as the Health Learning Package (HeL-Pack) developing for teacher to use as media while teaching in both onsite and online class as well as this HeL-pack can be used for flipped class or learner selflearning package. Additional significantly, these styles of learning media, can be considered to some extent and increasingly getting on superior impact and in some situations develop into mainstream themselves. As teachers grow into more familiar, frequently use with more confident as well as have better skills for online teaching and learning new technologies, these will bring more innovative instructional methods developing far and wild al all the time. Surrounded by the educational field, teachers are adopting, learning, and integrating new technological tools and utilizing them within their teaching practice to promote their learners to meet learning goals. Technology Learning approach focused on creating curricula and materials more extensively available using technology, as posting class materials online via many pathways such as YouTube, Line, Zoom, Google classroom, Blackboard, and more. However, learner must be trained, prepared with orientation to be able to use technology as tools of learning.

Autonomous learning has been a widespread concept in education field primary used in language learning the past decades, and it has been considered in relation to lifelong learning skills (Mun Shin Cheong, 2022). It has transformed old practices into new style of learning and applied to use for many contents subject learning approach. Learners currently need to use three main types of autonomous learning skills: 1) general learning or study skills, such as researching, making choices and decisions about one's learning; 2) language learning skills or abilities for different focuses, such as independent writing and revision skills, extensive reading; and 3) technology user skills , such as computer literacy skills, database management skills, website development skills, digital literacy skills, project management skills, and media literacy skills. Holec (1981) suggested autonomous learning means that the ability to be responsible for their own learning, by determining learning objectives and learning content, selecting learning methods, self-observing and self-assessing learning outcomes. In addition, Education Endowment Foundation, (2018) encourages teachers to develop their pupils' understanding of themselves as learners through awareness of their strengths and areas for development. As mentioned previously reflective practice supports the learners in identifying their future learning goals. Research

perspective also constructed the learning strategies as Rogue, et al., (2020) examined the learning of future health professionals is fundamental to the training of competent professionals. In this study, it was aimed to clarify the correlation between academic objectives and learning strategies in learners registered from the first to the sixth semester in seven areas of the Faculty of Health Sciences of the National University of Chimborazo. A correlational design was used to investigate via questionnaires for evaluation of academic outcome and strategies for autonomous learning strategies were employed. The findings indicated that the types of academic objectives and autonomous learning strategies had a homogeneous form in most of the seven specialties studied. The correlation between autonomous work strategies and the types of academic outcome of the learners in the sample was largely low or non-existent and direct. This study demonstrated that autonomous learning can be applied in health education or health science and in any other field, and the finding also suggested that to promote autonomous learning instructors or teachers need to be concerned with preparing student to learn how to learn when becoming an autonomous learning. This learning approach is very important for future skills of learning as a lifelong learner (McLoughlin and Lee, 2010). Especially in this Covid-19 situation, the online learning make learner to be self-directed person. To improve learners to assume superior self-control over their own learning it is critical to support them to become aware of and recognize the approaches that they already employ or could potentially use (James and Garrett, 1991). At any rate, particular learners differ in their learning patterns, interests, requirements, and motivation, and develop changing levels of autonomy through their lives (Richard, 2022; McLoughlin and Lee, 2010). Principles of Autonomous Learning include readiness, exercise, effect, primacy, recency, intensity, and freedom. Readiness implies a degree of willingness and eagerness of an individual to learn something new. Exercise states that those things most often repeated are best remembered (Omaggio, 1978). The Autonomous Learning Principles and Process should be concerned with be the insights into the learners' learning styles and strategies; take an active approach to the learning task for practice; willing to take risks, i.e., to communicate in the target language at all costs; be good guessers; attend to pattern and also to content; develop the target learning target into a separate reference system and are willing to revise and reject hypotheses and rules that do not apply; and have a tolerant and outgoing approach to the learning objectives. Moreover, Richards (2022) suggested five principles for achieving autonomous learning: 1) active involvement in student learning; 2) providing options and resources; 3) offering choices and decision-making opportunities; 4) supporting learners; and 5) encouraging reflection.

Candy (1991) states that autonomous learners can be describes that "autonomous learner should be trained to be methodical/disciplined, logical/analytical, reflective/self-aware, motivated/curious, flexible, interdependent/inter-personally competent, responsible/persistent, venturesome /creative, creative/have positive self- concept, independent/self-sufficient, skilled in seeking/ retrieving information, knowledgeable about/ skilled in learning, able to develop/ use evaluation criteria, Technology can play a big role in increasing the effectiveness of autonomous learning, especially in connecting, collaborating, and constructing learning"

Covid-19 Literacy and Health Behaviors, this study focused on Health literacy and Health Behavior toward Covid-19.

Covid-19 disease has increased the quantity of health information existing on online social network which created online information more complicated than they should be. The accurate information is very important for people to access and apply to understand the decease to prevent themselves and their community. Therefore, health literacy needs to be promoted.

Covid-HL Network (2021) state that "Health literacy is the ability to find, understand, appraise, and apply health information, is therefore more important than ever for people in order to navigate these information environments and use health information to inform their behavior"

Healthy People (2020) provides the new Health literacy that the ability to use health information rather than only understand it, ability to make "well-informed" decisions rather than "appropriate" ones, the ability to have responsibility to address health literacy and it should be incorporate a public health perspective. The primary well-known research, Nutbeam, (2000) and Schulz and Nakamoto (2005) suggested three component of health literacy; 1) functional health literacy described as basic reading and writing skills to understand and use health information, 2) interactive health literacy as advanced cognitive thinking skills to recruited with health-care service and to interpret; and 3) apply information to changing circumstances and as critical health literacy as advanced cognitive skills to analyze information to apply in daily life living. Interestingly, Chanuantong (2021) has synthesized by saying that:

"health literacy is still unclear. The conceptualized knowledge as the core of health literacy by describing health literacy as a "knowledge-based competency for health promoting behaviors. However, if we consider the Ottawa Charter, there is no knowledge component but there is a personal skill component, therefore it is possible to translate 'knowledge' into 'information' in the Health Literacy Approach. This argument needs more research support. What is most acceptable and agreed upon among professionals who conduct health literacy and public health literacy is the multicomponent or contextual component and the health outcome component. Therefore, in measuring the success of the program or policy, we need to measure the number of health literate people on the positive change of their health status rather than the level of knowledge change"

Consequently, Health information is key for people to be able to develop their understanding of health literacy toward covid-19 applying from the recommendations from international organization and many researchers related to health care to do to protect themselves and others. It is of extreme value that information creators and providers deliver information in the aspect of easy-to-find, easy-to-access, easy-to-understand, and easy-to-use health information. As well as health literacy should be concerned what the health status of the people rather than knowing information toward health care and prevention for wellness life.

Health Behavior Toward Covid-19

Health behavior is connected to heath knowledge, attitudes, and practices that simultaneously contribute to influence the actions toward health. Health behavior is very important issue as it can directly affecting humans' life living with wellbeing or not. To maintain, accomplish, or improve

better life as well as avoid disease. Health behavior reflects the health-related attitudes of an individual (Hildt-Ciupińska, Pawłowska-Cyprysiak K., 2020). Health behavior can be promoted though health education as education aim to change learners' behavior, knowledge, attitude, and practice. This study developed the content related to Covid-19 for the HeL-pack by applying the Classification of Health Care Functions which include cause and effect, symptom, prevention, curative care, and rehabilitation suggested by OECD/Eurostat/World Health Organization (2017). The learning activities in HeL-pack were also follow the suggesting designed by UNICEF Thailand (2020). In which teachers can apply or integrate the learning goals related to Covid-19 or can be able adapt the teachings and learnings about other transmittable diseases such as the hand, foot, mouth disease or influenza viruses.

Methodology

This qualitative research was conducted using semi-structured in-depth interview from 15 purposive samplings of 3 groups of 5 each, health educators, learners, and public health experts. This is a part of a research and development (R&D) study in Thailand context. This paper demonstrates the first part that consists of 2 steps. First, a needs analysis using Structural Equation Modeling (SEM) were conducted to determine what the learning package should include as the components. Second, the completed HeL-packwas analyzed using content analysis and qualified by 5 experts who have at least 10 years' experience in teaching both theories and practices, examined the HeL-packincluding content validity and determine index of item objective congruence (IOC ≥ 0.5)

Results

The outcome of the study includes HeL-packKits, modules, soft/hard copies, AV materials, Test Protocols. The package's components are as following.

1) The stated concept of Covid-19 literacy includes cause and effect, symptom, prevention, curative care, and rehabilitation and the content must be concerned with learners age, level of learning, or learners' background knowledge or health status.

2) the manual for HeL-Pack including guidelines to practice autonomous learning, application of using technology. Teachers or instructors must introduce how to practice autonomous learning by teach learner how to process and applying Autonomous Learning.

- a. Setting goals: Learners achieve by producing a list of goals to know where to start the learning procedure.
- b. Recognizing learning styles: students learn in different way, and, with autonomous learning, students can determine which learning style suits them best.
- c. Setting focus on improvement: Instead of focusing on grades, students underline learning objectives to establish success targets.

d. Support: Whether in a distance learning classroom or blended learning — with a mix of online and onsite instruction — learners need assistance to continue attentive and develop their cognitive skills.

3) Pre-test for HL and HB

- a. The HL test consists of four mail elements; what are the finding related to Covid-19 information? how to access the Covid-19 information, the accuracy of understand toward Covid-19, and where, when, and how to use health information toward Covid-19
- b. The HB test consists of three mail elements, which are knowledge, attitude, and practice.

4) Learning activities suggests to included online learning, blended learning, flipped learning, which is flexible learning. Learning materials can be posted online via many ways such as YouTube, Line, Zoom, Google classroom, Blackboard, but learner must be trained, prepared with orientation to be able to use technology as tools of learning at the beginning of process.

5) Learning materials must encourage interactions between learners and teachers, grow interchange and cooperation, and inspire active learning, provide feedback, emphasize time on task, communicate high expectation and should respect diversity of talent and learning in learners. The teaching and learning resources can be visuals aids, vdo clips, posters, flashcards, presentations, printed hard copy, textbooks, infographics, and application for learning via game, and or simulation.

6) Post- test for HL and HB can be used the same as post-test or using parallel tests if the learning process take less than 6 weeks as the learners may still remember the preset.

The result from experts shows that HeL-packwas qualified with IOC= 0.9 (Index of Consistency) and with suggestion to implement in different context of learners for further studies.

Originality/Value of the Paper

Through the developed HeL-pack, this program could:

- 1) Enhance the health literacy of participants on the different aspects of COVID19.
- 2) Improve participants' levels of health behavior- knowledge, attitudes, and practicestowards the control and prevention of COVID-19.
- 3) Promote lifelong skills in autonomous and technology-based learning approaches.

- 4) Strengthen capabilities of health and physical educators as program planners and implementors.
- 5) Develop sustainability among collaborators in implementing medium and long-term activities in the control and prevention of COVID10.
- 6) Promote cultural awareness in developing and implementing technology-based healthrelated initiatives among nations.

Conclusion

This Health Learning Package (HeL-pack) has synthesized based on Technology-Based with autonomous learning concept which aimed to enhancing health literacy (HL) and health behaviors (HB) for learners and people who can access to internet. The Hel-pack provides materials and guidelines for instructors and autonomous learners which qualified by experts in education. The beneficials of this pack are not only promoting HL and HB, but also lifelong learning skills. Moreover, lifelong learning has been identified as key to the success of sustainable development goal 4 (SDG4) and SDG 12 target 12.8, and quality education in the 2030 Agenda agreed by the United Nations member states since 2015.

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The Power of Educating Women and Ending Generational Poverty: A Comparative Study of Women in Ghana and Liberia

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Abstract

The movement of female empowerment throughout the world is not only affecting the livelihood of the individual, but the livelihood of entire nations. One of the most prominent forces of empowerment is education. When a woman is offered the opportunity to learn, whether formally or informally, she increases the capacity of her community to force its way out of oppression and raise the living conditions of her neighbors. There is a current struggle for education which is very present in West African countries. This struggle is especially apparent when considering female education rates in relation to the most developed countries in the world. This poses an immediate need to incentivize parents within these countries to send their daughters to school and finish their formal education. By addressing this struggle through incentive programs, we can see a greater access for young girls and a change in the cultural behaviors and values that surround this form of gender equality. This study delves into the why behind education affecting poverty, specifically targeting the ways that women allocate resources back into home communities and improve the experience of all members of society. All information will support the conclusion that as female education rates increase, poverty rates will decrease.

Keywords: Female Empowerment, Poverty, Educating Women, Formal Education, West Africa, Incentive Programs, Generational Poverty

Introduction

In accordance with target 4.5 of the United Nations Sustainable Development Goals, eliminating all discrimination in education is a goal that all should promote and protect. Barriers to the overall quality of education for adolescent girls limit the capacity for communities to address other issues such as health and wellbeing (SDG 3) and no poverty (SDG 1) (United Nations, n.d.). Due to education's deep connection to other goals for the United Nations, educating women should be at the forefront of goals for developing countries.

Education is a human right. Unfortunately, education equality is not present in a large portion of the world, specifically in Africa. Many factors are preventing young girls from attaining adequate levels of schooling. Levels of formal and informal education vary throughout Africa, but the trend is the same; young girls are at a major disadvantage in their ability to rise above and leave inequality behind.

Beyond education being a human right, there are reasons that educating women leads to the empowerment of societies and the standard of living increasing. According to the United Nations

Human Development Index, knowledge is part of the influencing dimensions. Knowledge funnels into the Education Index which combines mean years of schooling and expected years of schooling. These rates affect the level of development that a country is experiencing, and development affects poverty. The connection is thus created between levels of education amongst women and poverty.

To accurately discuss how education rates among girls in Africa affects the poverty statistics within a country, this study will compare African countries Ghana and Liberia. This comparison will consider many factors such as legal barriers, cultural acceptance, per capita GDP, and a comparison between female and male education rates, in order to display the trends that connect education to poverty. Both countries are located in West Africa and are affected by similar climate and demographic factors. This comparison thus focuses on laws and cultural barriers that are present in each country separately to understand the vast difference in female education rates in each country.

Types of Formal and Informal Education in Africa

Formal education is the main focus of this research; however, it is important to explain what parameters this includes and what other types of education are available for women. Formal education is structured education in a typical classroom setting. Most governments require formal education up until the 9th grade. Formal education also extends out of primary ages into secondary and post-secondary school.

Informal education differs in its structure and experience. It is known for its spontaneity and hands on experience. Informal education is not perfectly defined other than being considered any learning that occurs outside the natural structure of a classroom and its curriculum. Some common forms of informal education in Africa include:

- Song and Dance
- Oral Traditions about History
- Market Experience
- Apprentice Work within Families
- Spending Quality Time with Elder Members of Society

Informal learning has unlimited benefits, but it is not as easily created or monitored as formal education. Governments in Africa can have more direct impact on the quality and accessibility of formal education than that of informal. Consequently, our research will focus on the impact that

formal education has on African communities with the understanding that informal practices are also a necessity to the success of a country.

Who are the Stakeholders and What Power do they Hold

The children in Liberia and Ghana, both male and female are the primary stakeholders, yet have the least power concerning policy changes. The government of each country, and the parents of the children are the next most important stakeholders each with increased levels of power and control over the outcomes of a child's education. Under the law, parents have responsibility of a child until age 18. Once this age of maturity is reached, that authority is handed over to the individual. When examining formal education, the majority of the time spent in these settings occurs before the child turns 18. For that reason, parents are of great importance in this situation as they hold much power of the child's ability to attend school and access materials.

The government and government bodies hold the most power as far as changing conditions is concerned. Policy changes and precedents are of major importance in examining how conditions may be improved in the future.

The last group of stakeholders are third parties such as international non-governmental organizations and donors. The funding of incentive programs and scholarships is of vital importance and these groups offer an opportunity for added economic support.

All stakeholders are of great importance to the future of this issue. Every party must be actively fighting for the rights of female education because all parties will benefit. Throughout this research we will acknowledge barriers to education that occur for all stakeholder groups involved. We will also identify ways in which each party can benefit from this pursuit for increased levels of female education, as every party will benefit from the decrease in poverty rates. In order to address such an urgent issue, every single group must understand their role and their power to remedy the concern.

Understanding the Experience of Women Receiving Education within Ghana

Primary education rates amongst girls and boys in Ghana differs minorly. Enrollment rates given by the World Health Organization show 84 percent for males and 82 percent for females (World Health Organization, 2015). These numbers show more disparity when considering the income of the households that these children are coming from. Within high-income households 93 percent of boys and 87 percent of girls complete primary school. In comparison, within low-income families only 41 percent of boys and 46 percent of girls complete primary school in Ghana. (Clinton Foundation, 2015). To broaden the scope of education rates to include women and men (outside of the normal formal education ages) in the poorest households, the percentage of women with no education was 73.4 percent whereas the rates for men with no education were 54.7 percent (UN Women, 2016). These numbers show a larger difference in education rates comparing men and women than do the primary education rates of girls and boys. Two important questions are thus formed: Would the rate of educated women in the household have affected the chances of income to increase? And do these numbers show that generational poverty has stemmed from the previous generation not receiving formal education?

Transitioning away from education rates and statistics in Ghana, we now consider the barriers that impede girls' access to education. Legal barriers are not at play here as the law in Ghana states that Primary Education is free and compulsory. This covers education starting at kindergarten and going through to junior high (typically 9th grade). The government has also tried implementing a tuition-free enrollment for high school students that would help lower socioeconomic areas to still send children to school (US Department of State, 2019). If girls are legally protected to pursue their education, then we must consider other barriers that are preventing girls from attending primary school. Cultural views and values must play a part, which is true when understanding the focus of rural families on educating male children before their female children. A reason for this may stem from the outdated view that a man's ability to access wealth and properly use it is more than a woman's. Another reason may be that women are supposed to marry into a family that has already educated their son. While primary education may be stated in the law as equal and fair, that does not mean it is proving this in practice.

Another barrier that threatens girls in Ghana is rape and sexual assault. A study taken in Ghana found that perpetrators of rape were schoolboys in about 14 percent of cases against girls (Plan International, 2013). The physical and emotional threat that young girls face from their experience inside a school is affecting the likelihood of their desire to attend. In order to see positive change in the value of female education in Ghana there also needs to be a desire on the girl's part to continue schooling. The rape of girls also poses another threat when pregnancy occurs. The likelihood of a girl returning to school after giving birth to a child is diminished when there is no financial support, and the family is already living in poverty. The duty is then given to the young mother to stay at home and work or find other ways to provide for the child and the rest of the family.

Economic Situation Present in Ghana

To create an accurate comparison between Ghana and Liberia now we consider the economic situation present in the country. Ghana's GDP in 2020 was \$68.532 billion. This amount has steadily increased throughout the last 20 years and only seen minor dips that have been tied to health epidemics (World Bank Group, 2022).

Recent data trends show the decrease of poverty rates in the country. From 2011 to 2016 the poverty rate of \$1.90 per person per day decreased by 34.1 percent to 13.3 percent (World Bank Group, 2019). Ghana's poverty rates are below the mean poverty rate of Sub-Saharan Africa making them a leader in the region. Lastly, the per capita GDP of the country to further break down how the wealth is displayed in 2020 was \$2,205.529 (World Bank Group, 2022).

The Reality of Getting an Education as a Woman in Ghana

Analyzing the data supporting our thesis that the rates amongst female education lower poverty rates only goes so far to explain the complexity of the issue. We have already discussed some of the barriers that may have contributed to this situation, but a true analysis must inspect the reality and the urgency of the issue. The nuanced complexity of such low education rates can be explained in no better way than by asking for the experience of someone who has lived through the situation. For this paper we were able to interview an amazing individual who has exemplified the positive qualities that are required to rise above the injustice and continue her education beyond just primary school levels. Her identity will remain anonymous but let her experience be heard.

Subject A who we will call Lisa (name changed for privacy), grew up in Adenta, located in the Greater Accra Region of Ghana. Lisa's family was made up of biological and step siblings all being raised together by her mother. Her father worked as a public transport driver and her mother a trader. Her mother's job took her across the border frequently to collect and buy materials and products to sell back home. Due to both of her parents being employed and working throughout the day, Lisa started attending school at a very young age. She officially started Class 1 (equivalent to kindergarten in the United States) at the age of 6 and finished her primary education there at the local public primary school. While attending primary school Lisa vividly remembers having to bring her own school desk to class every day and then bring it home at the end of the day. That has now changed, and desks are already provided in the classroom. This is one example of how we have seen some positive progress. Lisa then continued on to her secondary education and once graduating decided to continue her schooling at the tertiary level. Getting into a university program at the local university was not simple for Lisa. In order to be accepted into the program that she had chosen she was required to write an application paper and then be selected by the school. Due to her hard work and dedication, she was accepted.

When asked about her proudest moments in her education, Lisa responded that her dedication to always maintaining a grade average of above B+ was something that brought her great pride. There were many sacrifices that she made while attending University and seeing her grades made difficulties such as missing meals not feel quite as harsh.

Delving deeper into the complexity and the "why" behind these statistics we followed up our interview by asking Lisa if she ever felt at a disadvantage in school purely because of her gender. There was an immediate reply of yes, and many stories to back this up. This first story that she shared was one of great significance - when she had her first menstruation as a teenager. Without quality sanitary products or medication to handle some of the harsh pain that comes for some women during menstruation, the women in her town had to miss school almost every month. Watching her brother leave to go to school was very difficult for her, not only because she was missing out on the learning that she so loved but also because of the shame and embarrassment that was often associated with a woman's period. The experience of women in education has changed throughout her own lifetime especially when looking at things through the perspective of her own mother's experience. Lisa's mother dropped out of school in Class 3 (equivalent to 1st

grade) in order to sell items to make money to continue sending her brothers to school. This progress was not instantaneous and still does not address all of the problems that surround the topic. In fact, Lisa remembers that when school began the very first person to receive their books were the boys. If the family could afford more, then the girls could have their own required material. If the family could not afford said materials, then that child was not able to perform correctly in the classroom.

Lisa was always very passionate about sports. She connected with mostly boys at school because they seemed to share this love more than most of her female friends. It was always very difficult for Lisa when it was time for PE class. The boys were the ones who were allowed to stand up and play sports together, and the girls were expected to sit down and cheer on the boys. Physical Education is of great importance to children and a way to use their bodies for movement while also learning valuable lessons and skills. School girls were deprived of this opportunity and the gender inequality seemed to continue.

Another example of inequality in the classroom occurred simply because of the view that the boys' opinions were superior than the girls - if a question was asked by a teacher and both girls and boys raised their hands, the boys would be chosen. If there was a chance that a girl was finally picked, and she answered the question correct, then the entire class would applaud as if she had done something extraordinary and unlike what she was supposed to. The act of applauding an answer should have been a sign of pride but instead it was another way to minimize the capability of the girls in the classroom.

Where does this value of male education above female reside? Is it purely a conceptual idea that men are superior or is it a notion that men have more earning capacity than women? Lisa explains that most of the problem comes from this internalized misogyny that has led these native groups to see men as more worthy of respect in society. A second reason is because of this idea of carrying on the family name. Girls are raised to marry and become the wife of another man of whom they take his name. The boys of the family will continue to grow up and keep the family's legacy and so the family should be more invested in his success. This view of gender roles plays a huge part in why education is not equal, and how could the inequality that is present in society be so easily changed inside a classroom unless there is outside influence? These cultural values continue to place a huge barrier on fixing the imbalance.

One of the most important beliefs that Lisa speaks on is her value of her own daughter's education. In fact, throughout conversing with Lisa her body language and tone of voice was never so enthusiastic or passionate as when she spoke about how important it was for her daughter to get her education. Through self-reflection of her own experience in education, Lisa could see how vital her knowledge had been in the family's ability to remove itself from poverty. Though she was having to give up much to send her daughter to a quality private school, there are sacrifices that she will continue to make knowing that her daughter's education will be the greatest asset she can take into her future. Lisa understands the necessity that finishing education in her country is. If her children are to not return to poverty, then they must have an education to support their professional endeavors. Having her own education completed at such a high level

is a way that Lisa is able to help provide for her family, and also feel empowered in her own worth as a woman. She can see the correlation between education and poverty in her own life experience.

As already mentioned, the rates of education and poverty are only a glance at the importance of educating women. Is not the example of this mother's desire for her child to finish her education proof enough that education holds power? Not only are we trying to quantify the connection of present poverty rates, but we are also trying to see a connection that explains generational poverty and the perpetuation of impoverished communities. The lived experience of Lisa points to the intimate connection that women feel with their own empowerment. Women teaching each other the things that have helped them in their struggle to find power in society. A mother helping a daughter navigate her way through society and showing her how she can use her voice. All ways that empowerment is being explored in these communities.

Lisa raises an important idea that has not been the major focus of this thesis but could point to a direction that we could go as we continue forward. The main focus of this paper has been researching the rates of formal education and their connection to poverty, but not necessarily the level that this should encompass. When asked about what possible changes she would want for the future of Ghana's education for women, Lisa contends that free education should extend outside of primary school and all the way to the tertiary level. If women have the ability to continue their education to such a high level, then parents cannot argue that there is not as much reason to value their daughter's education as much as their son's. Preventing the economic barrier that impedes on girls' ability to receive their education is one of the fastest ways to see positive change and growth in both Ghana and Liberia.

Experiences and Barriers that Face Women and Young Girls from Receiving Education in Liberia

The law in Liberia is the same as Ghana; Primary education is free and compulsory. Societal barriers and practices may show the biggest difference.

- 1. There is no legislation on sexual harassment in education (The World Bank, 2018).
- 2. An increasing number of girls are dropping out due to pregnancy (United Nations Human Rights Treaty Bodies, 2018).
- 3. Fees are required for senior education levels (grade 10-12) (US Department of State, 2017).

While education is compulsory in Liberia, there is no real data to suggest that this is enforceable. Many girls are having to stay home and help provide for their family by selling items on the street or working in markets. When a family is only able to send one child to school it seems that this preference is almost always given to the boys. These practices are directly affecting the ability of girls to complete their primary education and continue forward to other secondary levels.

Next, we compare the number of girls and boys finishing their primary education in both high- and low-income families. Only 8 percent of girls and 17 percent of boys in low income homes complete their primary education, and 59 percent girls and 64 percent boys in high income households (Clinton Foundation, 2015). These numbers are already significantly lower than those shown in Ghana. The next subject would be to also consider those within the home who may have already passed standard primary education ages, particularly, those who are in the poorest households. In Liberia 73.2 percent of women in the poorest homes do not have any education, 20.5 percent have primary education, and the rest have secondary and tertiary levels of education. Men in these poor households, however, are significantly more likely to still receive primary or secondary education. In comparison to women, men with no education accounted for 36.2 percent (UN Women, 2016).

Economic Situation in Liberia

Now we analyze the economic situation present in Liberia to further understand the connection between poverty rates and female education. The GDP in Liberia as of 2019 was \$3.32 billion. The country has also seen a steady increase in GDP over the last 20 years (World Bank Group, 2022). In 2016 Liberia's poverty rates were recorded at 44.4 percent. This is according to the headcount ratio standard that calculates poverty at \$1.90 a day per person. In comparison to Ghana, roughly 31.1 percent more of the population of Liberia is living in poverty. Liberia's rates sit well above the international standards and classify Liberia as a very impoverished country. Much of Liberia's present economic situation can be attributed to the aftermath of the first civil war in Liberia that lasted from 1989 until 1996. A resurgence of war and violence came about later and lasted until approximately 2003. The consequences of this war included many families being displaced and left with incredible hardships. In recent years, Liberia was also damaged by the Ebola outbreak. (Liberian Economic Group, 2019).

By comparison, Liberia is in a much worse economic condition than Ghana. Education rates suffer as a result of poor conditions. In fact, the country has one of the world's highest levels of children ages 6-14 years old who are not in class (Unicef, n.d.). Education rates continue to be a critical indication of a country's stability in its economy and standard of living. As shown in the data collected on these two countries, that unfortunate truth of unsatisfactory education rates proves even worse for the life of a young girl.

Comparing Data from Liberia and Ghana to Find a Connection between Education Rates and Poverty

Now a deeper understanding may be formed when considering the question asked when analyzing education rates in Ghana: Would the rates of women with education have changed the amount of those living in poverty? The amount of people living in the poorest conditions is lower in Ghana than in Liberia, yet the percentage of men in these homes with no education is greater

in Ghana. Consequently, the percent of men with education did not have a direct effect on the amount of those living in poverty. While many of the connections in this paper are theoretical, they are founded on conclusions made from data. A theory that we consider is that the number of families living in the poorest conditions is more directly tied to the female in the household's education status than that of the man. Thus, calculating the probability of a family living in poverty is tied to the education level that the woman received.

Understanding why the Educational Success of Women in the Home Leads to the End of Generational Poverty

The central goal of this study was to find a connection between female empowerment, education, and poverty. Now that a connection has been established, we must consider, why? Why does educating women lead to lower rates of poverty? Is it simply because more jobs are created? Even so, what is stopping her from leaving the home environment and escaping to better living conditions elsewhere? Thus, we now analyze the how women affect their communities and where they choose to spend their money.

It is estimated that countries sustain more than \$1 billion in losses for inadequately educating girls. Women are more likely to remain in their communities and effectively trickle down their economic success to their children (stopping generational poverty) and give back to their community. The most important effect of educating women has been stopping generational poverty. Women spend more money on food and education for their children and education is a proven way to stop poverty (McCartney, 2018). The woman's ability to focus her own success as a way of empowering her own children creates a positive cycle to combat the negative cycle of generational poverty. Lisa's own passion for her daughter's education is the perfect illustration of this powerful exchange at work. Halting poverty rates in the present is of huge importance, but long-term intervention of generational poverty is of equal importance. Educating women serves both purposes.

Changing Cultural Opinions and Translating Values to Needs

There is an argument to be made that poverty is not a result of education inequality and instead that education inequality only exists because of poverty. Many young girls are having to stay home and take care of elderly family members, help make small amounts of money, or trade work for food. These endeavors take them out of school only because they do not have the financial security to stay in class. Regardless, of which resulted from the other, both poverty and education inequality exist in Africa. It is harmful to suggest that these education rates will only be improved once the poverty rates decrease. The correlation has already been created between the two and education rates appear easier to target. Therefore, the values of these African countries in terms of female education must be translated into needs. If there is no longer "just a desire" to educate women and instead a need, pressure will be put on external forces, such as the government, to support and incentivize.

Historical societies have created precedent for the view of women and feminine roles in society. As seen in research of Ghana, families are more likely to only send their sons to school than only their daughters. Misogyny exists within individuals as well as within education systems. The expansion of female political representation, and the effects of globalization are slowly changing the values and needs of societies, but they are not addressing larger systemic issues quickly enough in rural and urban areas of Africa. Education needs to be a basic human right, and gender equality must also. With that in mind, how can we attack the barriers that are preventing these human rights?

First, we attack the attitudes. This means more representation of women in power and therefore a precedent of increased instances of women in the highest levels of government and the private sector. If young girls can have tangible examples of their capability to achieve greatness as a result of their education, we have accomplished one of the most empowering feats. Not only are we then changing the attitudes of the child, but the attitudes of the parents seeing how their daughters have the same financial earning potential as their sons.

Next, we make school conditions safer. Sexual assault and rape are two words that should never be associated with school. If current precedent is in favor of teachers and school boys getting away with exploitation, then new precedent must be set. Harsher sentencing for sexual violences occurring in schools is one answer. A child should not have to fear physical harm while in the pursuit of education.

Incentive Programs for Economic Relief

The last, and seemingly most pressing barrier stopping girls from finishing their education is economic distress/poverty. Third party assistance may be the quickest way to address limits and financial struggles. USAID alongside other donors and international NGOs have already made strides in supporting education and access for girls (Miller-Grandvaux, 2004). The international community is in agreement that quality education is a goal that can be achieved if resources and infrastructures are offered. In order to accomplish these goals; agreements also need to be made with third parties and government systems. This is where we suggest incentive programs and scholarship opportunities that are both funded by third party and government. These incentive programs would be focused on aid for struggling families and the scholarships would be given under the criteria of academic success. If the main reason that girls are not attending school is because they are having to remain at home and make money, then their participation in school should offer them that same financial protection. Quotas for school days attended can be created for the girls and rations given if those required days are attended, incentivizing the parents to send their daughters to school.

Once the attendance issues are addressed then the quality and success of education will be aided in scholarships. Academic success should be rewarded with financial rewards for the family to motivate children and parents. Addressing the issues of getting girls to school is only the first step. The quality of the education itself must be the next. No child should have to encounter the same demoralizing instances of inequality as Lisa did when the boys were the only ones called on in class. If poverty rates and standard of living are of such high value in society then we must acknowledge the role that education plays in shaping the outcomes. Quality education should be synonymous with equality of education. If girls are not given the same rights to their schooling as boys, then quality education has not been accomplished.

Societies that have refined education systems have better economic conditions. These conditions are most likely sustaining the ability to offer quality care to students. Ghana and Liberia are not given the same privileges. There needs to be a way that education is valued before these conditions are present so that they too can be sustained and perpetuated when better financial conditions become present.

Just as the home countries themselves must translate their value of female education to a need, so must third parties. The international community must be in support of a push to incentivize parents and correct the low attendance and graduation rates in these West African schools. The urgency of eradicating such poor living conditions and high rates of poverty must transcend any cultural barriers. Creating a solution to correcting these rates is no longer just a desire but a necessity.

At the heart of any third party intervention must be the desire to create quality education standards and gender equality within the classroom. By promoting a sense of equality within the classroom it is very likely that the experience of fairness will transcend the classroom setting into the homes. Regulating behaviors and values occurring inside the walls of children's homes is difficult to create. However, in a professional classroom setting under the policies on curriculum and conduct such regulation can be achieved. Creating a safe environment for young girls to study and propel themselves and their families out of poverty is achievable when resources are allocated towards the education system.

Conclusion

The data from the analysis has indicated that as education rates of women increase the negative cycle of generational poverty is decreased. Addressing the issue with a short-term mindset is not invalid as there is an urgent need to stop the present rates of poverty and education inequality in both Ghana and Liberia. A long-term perspective is also needed to combat generational poverty. A mother's determination to offer her child quality education and use her own successes as a way of financing that education will stop generational effects of poverty in her home.

The human desire to learn and be empowered must be supported by governments and international committees. As mentioned previously, formal and informal education is vital to the development of a country. The eagerness of these bodies' involvement in formal education rates may open up other channels and opportunities for informal learning. These two modes supported by one another can combat many of the lasting effects of war, health crises, and poverty that are so present in Liberia and Ghana.

Finding a connection between rates of education and poverty was not difficult when looking at the data trends of both countries, nor was it difficult to see in the experiences shared by Lisa. She is a living reminder of all that can be accomplished through hard work, but what needs to change so that what was once hard can be made easier. Her story is one of power but also one of exposure to injustice. She accomplished more than what was expected of her and now she desires the same for her own children. Her value of education is now tied with strength and success and that is the way that she wants her children to value their own learning. She has seen how education gives her and those around her the power to create a better life for themselves and their families.

In order to create these opportunities for education a priority must be placed on economic intervention so that proper funding can be contributed to families who are seeking to educate their children and especially their daughters. As rates of girls dropping out of school to work remain high the empowerment and equality of the sexes will remain low. Giving girls the access to quality education and providing them with examples of success will strengthen their own desire to find power within themselves.

The power of educating women and ending generational poverty enhances the need of countries to improve their education systems. Education is a common theme in all Sustainable Development Goals as knowledge promotes safety and equity. As seen through the research in this paper, educating women will directly impact a community's ability to free itself from the bondage of poverty and address other obstacles mentioned in the SDG targets. Equality in education must be a primary concern as the women who are not receiving their needed education may become more exposed to other direct and indirect gender-based violence and unable to further assist in the future of peace and prosperity for the planet.

As we continue to move forward and develop as a global community, we cannot leave behind the communities whose children are in desperate need of education. The right that is so admirably given to women around the world is not equally presented in every country. This right to education is not only congruent with a desire for quality education but it is a right that pushes for the opportunity to reach gender equality throughout the world.

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Who Gets to Choose? A Global Perspective on Gender, Work-Life Balance, and Choice in the Post-Pandemic Workplace

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Abstract

Post-2020, there is evidence of persistent gender inequities both at work and at home, which research has shown can limit women's work choices. Thus, it is urgent that we investigate gender differences in domestic responsibilities among working parents and the potential impact of these differences on work choice. Using an original dataset with employees who have internet access in select countries in North America, South America, Europe, and Asia (N=3,147), we conducted logistic regression analysis to explore whether employees felt they had a choice in where they do their work. In addition to gender, we considered how childcare responsibilities, housework responsibility, self-identified "minority" status, education, workspace model (hybrid, remote, inoffice or on-site), and country influenced employee perceptions of choice. Notably, in addition to significant differences between countries, education, and according to "minority" status, we found that men (OR: 1.23; 95%CI 1.04-1.47) and those stating that a partner was responsible for all or most of the housework (OR: 1.45; 95%CI 1.06-1.98) and childcare (OR: 2.72; 95%CI 1.95-3.78) reported feeling they had more choice regarding where they work. Additional chi-square analyses found significant gender differences in the distribution of housework and childcare responsibilities. These results suggest that working women still shoulder more of the childcare and housework responsibilities globally, and this unequal distribution of responsibility could have an impact on women's perceptions of their choices when it comes to work.

Keywords: Gender, Work, Work-Life Balance, Working Parents, Gender Inequality, Work Choice

Introduction

Global feminist scholarship has established the importance of gender for experiences with paid work (Baxter & Wright, 2000; Bobbitt-Zeher, 2011; Leidner, 1991; Miller et al., 1991; Misra et al., 2021; Murray, 2000). For instance, research has repeatedly shown that persistent gender expectations task women with balancing paid work and childcare—pressure that men typically do not experience (Hays, 1996; Hochschild, 2003). Across the world, gender norms have consistently impacted women's career choices and trajectories for more than thirty years, to the extent that some scholars have pondered whether many women actually have career "choices" in the same manner as men (Blair-Loy, 2005; Glass, 1988; Kan et al., 2022; Massey et al., 1995). For example, several studies have found that women's choices can be constrained since women often feel compelled to make certain decisions due to gender expectations (Blair-Loy, 2005; Corby & Stanworth, 2009; Williams, 1991). Particularly given emerging evidence that the pandemic has

made the task of balancing work and family increasingly difficult for women despite burgeoning remote and hybrid work opportunities (Collins et al., 2021; Dunatchik et al., 2021; Mooi-Reci & Risman, 2021; Russell & Frachtenberg, 2021), investigating gender differences in perceptions of choice at work—and additional factors that relate to perceptions of choice—could reveal insight into which issues are currently impacting women when it comes to work choices. Removing any extant barriers could be key to fostering greater equity.

Thus, we use data from original surveys with employees across the world (N=3,147) and a feminist theoretical lens to explore gender differences in employee perceptions of choice in where they do their work post-2020 as well as how employees' current childcare responsibilities, housework responsibilities, workspace (hybrid, on-site/in-office, or entirely remote work), self-identified "minority" status, education, and country might matter for perceptions of choice. Using logistic regression, we found that partner responsibility for childcare and housework predicts increased perceptions of choice, while the inability to work remotely at least part of the time and lower education levels predicted diminished feelings of choice. We also found significant differences among countries, which suggests the need for more cross-country comparisons of this issue. Further, using chi-square tests, we found significant differences between women and men concerning self-reported responsibilities for housework and childcare. Our findings suggest that gender inequities in work choice are persistent in the post-2020 workplace. While not a complete solution, we propose that taking steps to equalize gendered responsibilities at home and at work will seemingly help equalize feelings of choice at work, and thus, support gender equity.

Background

Gender Discrimination and Stereotyping Pre- and Post-2020

Although there is evidence of exacerbating inequities among workers based on race, class, and gender lines since the beginning of the COVID-19 pandemic (Mooi-Reci & Risman, 2021), feminist researchers have a long history of capturing evidence of gender inequity at work. This scholarship helps provide insight into how gendered ideas that exist at the structural level continue to matter for individual women's work choices. For instance, gender stereotyping and discrimination in the workplace are two such elements that can ultimately impact individual choice.

First, gender discrimination continues to play a significant role in shaping outcomes for women in the workplace (S. Fiske, 1998; B. F. Reskin, 1988; Ridgeway & Correll, 2004; Ridgeway & England, 2007). Over the last thirty years, studies have continued to find evidence of discriminatory practices at every stage of the employee life cycle, from hiring practices and job classifications (Acker, 1990; Goldin & Rouse, 2000; Gorman, 2005) to wage disparities, promotions, and authority lines (Meitzen, 1986; Olson & Becker, 1983; B. Reskin & McBrier, 2000). Yet despite the increased attention paid by scholars and practitioners over the past three decades, discrimination continues to be a barrier to gender equity at work (England, 2006; Gorman, 2005).

How can we explain continued discrimination despite repeated calls for addressing this issue? There is broad consensus among scholars that cultural beliefs about gender are foundational to discrimination in the workplace, and that the persistence of these beliefs helps fuel continued inequality (S. T. Fiske et al., 2002; Ridgeway & England, 2007). In general, these gender essentialist beliefs advance depictions of men and women that support the idea that women and men are fundamentally different kinds of people—and thus, will have different outcomes as workers. These efforts at categorization subsequently facilitate gender stereotyping, which leads to discrimination in many workplace contexts (Ridgeway & England, 2007).

Regarding stereotypes, there are two types (descriptive and prescriptive) that can help explain the link between gender stereotyping and workplace discrimination and inequality (Berger et al., 1972; Burgess & Borgida, 1999). Descriptive stereotypes are shared beliefs about traits and abilities that men and women possess. For example, one descriptive stereotype is the idea that men have agentic qualities associated with leadership, such as competence and assertiveness. Conversely, women are assumed to possess communal qualities associated with helping and nurturing, such as warmth and empathy. Discrimination based on descriptive stereotypes results when one gender is perceived as unfit to perform tasks associated with qualities believed inherent to the opposite sex (Eagly & Karau, 2002). In this context, men are seen as naturally suited for agentic occupations such as a lawyer or doctor, while women are believed more suited for nurturing occupations such as a nurse or counselor.

If descriptive stereotypes derive from cultural beliefs about what men and women can do, prescriptive stereotypes arise from cultural beliefs about what men and women should do. Like their descriptive counterpart, prescriptive stereotypes align with the agentic-communal dichotomy. However, prescriptive stereotypes are fundamentally normative, and thus prone to greater socialcultural disapproval and sanction for those who violate them (Burgess & Borgida, 1999). While studies suggest that men who display attributes counter to prescriptive norms (less assertive, more empathetic) risk minor forms of professional disapproval (Connell, 1995), women who violate their prescriptive stereotyping (particularly in the workplace) face penalties on numerous levels (Rudman, 1998). When a woman succeeds in a masculine role, she signals competence but can violate prescriptive gender norms. In this context, the assumption is that her possession of successful agentic qualities also reflects a deficit of stereotypically feminine communal qualities. The resulting double-bind places her in an unwinnable situation: she can be seen as competent but not likeable, or she can be viewed as likeable but not competent. Consequently, assertive women in high-status roles are frequently viewed as hostile, cold, or aloof, negative attributions that move organizations to penalize successful women when it comes to rewards such as salary, opportunity, and hiring (Heilman, 2001). By contrast, men are not penalized for behaving in assertive, agentic ways (Rudman, 1998).

Unfortunately, gender stereotypes and discrimination continue to be problems in workplaces across the world despite calls for more awareness of these issues. For instance, since 2020, scholars have clearly captured global patterns of work inequality by demonstrating that women (and especially women of color) have faced rising levels of stress and job precarity that likely relates to how valuable employers view them in economically unstable times (Mooi-Reci &

Risman, 2021). This treatment adds insult to injury, as due in no small part to gender stereotypes, working women have historically also shouldered much of the day-to-day responsibilities associated with home life as well.

Gender and Balancing Work and Family Pre- and Post-2020

The rootedness of the idea that women are caregivers first and employees second can be seen in research on the "second shift" (Hochschild, 2003). Developed in the late 80s, Hochschild argued that the advancement of gender equality in the U.S. economy had stalled due to what she coined as the "second shift"—the unpaid work of childcare and housework after already completing a "first shift" of paid work in the workplace. In Hochschild's research, the "second shift" was overwhelmingly taken on by women, and more recent research has found evidence that the gendered aspect to the "second shift" continues today on a global scale (Dunatchik et al., 2021; *Women in the Workplace*, 2020).

Nearly three decades later, the scholarly consensus is that the move towards gender equality in the workplace remains fundamentally stalled (Blair-Loy et al., 2015; Hochschild, 2003). Despite notable advances for women in education and income, many of the challenges originally identified by Hochschild remain unreformed: there continues to be a lack of gender balance in housework and caregiver work, and organizations remain overwhelming structured around the construct of an ideal worker who is always available and committed to work. As one scholar summarized, "women still face fewer opportunities for work involvement, pay, and public life while men spend less time with their children" (Blair-Loy et al., 2015). Even institutional features that outwardly appear to promote or even advocate for women employees ultimately formalize male privilege in the workplace and reinforce hierarchical orders of status inequality (Ridgeway & Correll, 2004). For instance, policies that exclusively support maternity or caregiver leave for women (without providing equal policies for caregivers of any gender) risk reinforcing stereotypes that predominantly associate women with communal qualities of nurturing (in addition to the idea that men don't need caregiver leave). The unintended consequence of aligning organizational policy with a descriptive stereotype that paints women as family caregivers first and as workers second, suggesting that their role as potential mothers or caregivers makes them less invested as employees (Bobbitt-Zeher, 2011).

While pre-pandemic assessments of gender equality in the workplace are troubling, one question remains unanswered: does this view of women's experience in the workplace apply to the current work environment characterized by radical changes in schedule and location flexibility? Unfortunately, according to most current research, the answer is yes (Dunatchik et al., 2021; *Global Gender Gap Report*, 2021; *Women in the Workplace*, 2021; Mooi-Reci & Risman, 2021). Despite the widespread acceptance of flexible remote and hybrid work models, as well as new technology designed to streamline collaborative work across multiple locations, women continue to experience significant stress and exhaustion in addition to magnified domestic responsibilities (Collins et al., 2021; *Women in the Workplace*, 2020; *Women in the Workplace*, 2021). Additionally, women continue to experience persistent gaps in the corporate pipeline, with promotions at initial steps towards management being both inconsistent and inequitable

(Dunatchik et al., 2021; *Women in the Workplace*, 2021). Women leaders are increasingly taking on additional responsibilities, both in supporting their teams and advancing diversity, equity, and inclusion (DE&I) initiatives, yet relatively few are being recognized for their contributions. Overall, today's ongoing gender discrimination and lack of support—both domestically and institutionally—echoes the unfavorable experiences of previous generations (*Women in the Workplace*, 2021).

Collectively, the picture that emerges from the literature highlights the ways compounding gender pressures constrain the choices women have about their work. Even before entering the workplace, gender beliefs about abilities and limitations bias both individual and institutional expectations that, in turn, define (or limit) the professional opportunities that are made available for women. Once inside the workplace, those who choose to push beyond the constraints of gender stereotypes sometimes pay for their professional success with the interpersonal hostility and disapproval that comes with choices that violate prescriptive norms (Heilman, 2001). In addition to externally imposed constraints on choice, women are also forced to wrestle with the self-limiting internalization of gender bias (Foschi, 2000; Ridgeway & Correll, 2004). Genderbiased self-perceptions of ability (which are rooted in structural ideas about gender) can discourage an individual from making decisions that would otherwise advance their professional standing. In terms of amplifying personal and professional need fulfillment, even recently expanded options for hybrid and remote work models are something of a false-choice for women. The ability to capitalize on the flexibility and opportunity these work models afford is frequently compromised by childcare and housework responsibilities that continue to disproportionally fall to women (Dunatchik et al., 2021). Whether at home or in the office, complex layers of gender discrimination continue to negatively impact how women perceive choice and opportunity at work.

Methods

The survey data used in our analyses were gathered in the fall of 2021 as part of a monthly survey project carried out by the authors' institution. To qualify for the survey, participants had to be working at organizations with at least 500 employees in one of the following countries: the United States (n=858), the United Kingdom (n=605), Canada (n=472), India (n=795), and Brazil (n=417). We targeted English-speaking participants in these countries since our survey only fielded in English. We used Alchemer software to build the survey and Lucid marketplace to screen and administer the survey. Lucid is a sample aggregator that enables direct-to-respondent sampling through its marketplace platform, reaching potential respondents via a number of panel providers (Coppock & McClellan, 2019). The panel providers compensate respondents for their time in the form of cash or reward cards and redeemable points. Payment for this survey ranged from \$1.25 to \$1.85 USD per respondent, depending on the country (adjusted for cost-of-living and to attract respondent interest). Our survey is comprised of a convenience sample and is thus not representative of all workers in the sampled nations. For instance, participants had to have internet access and be English-speaking to take the survey, which limited our sample somewhat. However, our sample is large enough to generate meaningful results.

Survey and Instrumentation

After we posted a survey to the Lucid platform, panel providers contacted potential participants who were then taken to a screener for our survey that included a consent form. Respondents were informed that they could exit the survey at any time. Opting out of the survey did not hurt participants' quality scores with panel providers. Surveys then asked participants a series of questions related to their experiences in the workplace, including their experiences with diversity, equity, and inclusion at work as well as demographics. Our survey also asked about their domestic responsibilities (housework and childcare) outside of work.

Analytic Strategy

We used StataMP 17 to generate both chi-square tests and our logistic regression model. Our dependent variable in both analyses was participant self-reports regarding whether they felt they had a choice in where they do their work. While the "choice" in where one does their work can be somewhat limiting depending on the field, emerging research demonstrates that more educated workers and "knowledge" workers (or, those whose jobs require they work with information) are more likely to have choice in where they work, typically due to the feasibility of conducting knowledge work remotely (Auginbaugh & Rothstein, 2022). Indeed, our survey skews toward a more educated sample (87% of participants have at least a high school diploma or equivalent). Thus, it is suitable to explore perceptions of choice.

In addition to education, gender, and workspace (remote, hybrid, or in-office workers) we explored how self-identified minority status and housework and childcare responsibilities might matter for perceptions of choice since previous and recent work has suggested that they may (Auginbaugh & Rothstein, 2022; Blair-Loy, 2005; Glass, 1988). We also compared across countries due to a lack of research using international samples to investigate this particular issue. Lastly, we conducted chi-square analyses comparing housework and childcare responsibilities across gender, since gender inequalities are our main focus in this paper.

Findings

According to the logistic regression test, all independent variables demonstrated statistical significance in some respect. Full results of the test are available in Table 1. The pseudo-R2 of our model was 0.2269, which indicates good fit. Consistent with our expectations, we found that men were more likely to express optimism around work choice. Perhaps unsurprisingly, we also found that those working in hybrid or remote environments also expressed greater optimism around choice. Interestingly, we found that minority-identified workers also expressed significantly more optimism around choice. Lastly, we found that compared to the United States, those in India and Brazil were significantly more likely to express optimism around choice.

At the same time, when it came to housework, we found that compared to those respondents who reported that they were mostly responsible for housework, those who attested to living in a
household where *partners* were mostly responsible for housework were more likely to express optimism around choice. Interestingly, compared to respondents with no children, those with children were all more optimistic around work choice. However, those reporting partner responsibility for childcare were the most optimistic (see Table 1). Exploring these patterns further, additional chi-square analyses found statistically significant differences according to gender when it came to both housework and childcare. Men were significantly more likely to report that their partners had responsibility for both the housework and the childcare, whereas women were significantly more likely to report that they were responsible for both in their households. These results are reported in Table 2.

Discussion and Conclusion

In this paper, given past research into the impact of gender on work choices (see (Blair-Loy, 2005), we sought to explore gender differences in employee perceptions of choice in where they work. In addition to differences in childcare and housework responsibilities, by including in our models an international sample of key employee characteristics historically associated with gender inequities at work, we contribute to the growing body of literature in global gender equity in the workplace (Hideg & Krstic, 2021). While some of our results echo the gender challenges highlighted in previous studies, our findings also provide some compelling insights that can be used to inform future research and practices in workplace gender equity post-2020.

With respect to the gender gap in domestic work, we found little evidence that the division of labor between men and women has become more equitable. Men are consistently more likely to express optimism around work choice, as are those individuals whose partners are responsible for household labor. Unfortunately, our study found that when it comes to household labor, women continue to bear primary responsibility for childcare and housework. One aspect of the domestic dynamic that merits future exploration is our finding that respondents with children felt more optimistic around work choice. While this might suggest a positive impact on perspective from the additional support children might potentially bring to household tasks, more research would be necessary to account for this increase in optimism.

Perhaps unsurprisingly, we also found that those working in remote and hybrid environments were more likely to express optimism about work choice. Although our study did not specifically test whether individuals were given the option to choose their work location, the post-Covid implementation of hybrid and remote work schedules has largely been in response to employeedriven expectations of greater flexibility and choice (*Future Forum Pulse*, 2021). As such, these work location options could be broadly construed as the result of employee work choice, although further research would be required to confirm this observation.

Lastly, we found that minority-identified workers expressed significantly more optimism around choice in where they work compared to their non-minority counterparts. While compelling on its own, this finding signals some potentially interesting areas for additional exploration. Current research finds that the desire for flexibility in work location—specifically remote—is strongest among underrepresented groups (*Future Forum Pulse*, 2021). That minority employees in our

study are expressing optimism about choice in where they work suggests a potentially positive move in diversity, equity, and inclusion efforts. However, the desire of underrepresented workers to overwhelmingly move to remote work environments should also raise questions about potential inclusivity, bias, or discrimination issues that might be informing the shift away from the office. Additional qualitative research could provide more nuanced insight into the complexity of this particular finding.

Our research is not without limitations. First, since our sample is one of convenience, we cannot generalize our results to all workers in the countries that we sampled. Our research is also limited in that our survey was administered electronically, so any potential participants would need access to technology and an internet connection in order to participate. Yet despite our limitations, our research provides insight into gender differences in perceptions of choice at work. While hybrid and remote work opportunities hold out the possibility for greater flexibility and work-life balance, continued gender inequity in the division of domestic responsibilities disproportionately impacts women and how they perceive their work choices. As such, organizations should question whether their policies facilitate gender-equitable practices or are they complicit in perpetuating gender stereotypes that spill over into the home. We should also continue to question how gender stereotyping in the workplace impacts not only women's choice in where they work, but also the opportunities they have for professional advancement, growth, and contribution.

Table 1: Logistic Regression Results Comparing Demographics and Perceptions of Choice at Work

Characteristics	Odds Ratio	95% Confidence Interval
Gender		
Women (ref.)		
Men	1.23†	1.04-1.47
Workspace		
On-site (ref.)		
Hybrid	4.98**	3.97-6.26
Remote	4.58**	3.79-5.54
Housework		
Respondent Responsible (ref.)		
Shared Responsibility	0.82	0.65-1.02
Partner Responsible	1.45†	1.06-1.98
Childcare		
No Children (ref.)		
Respondent Responsible	2.20**	1.73-2.81
Shared Responsibility	1.73**	1.38-2.18
Partner Responsible	2.72**	1.95-3.78
Minority Status		

No (ref.)		
Yes	1.45**	1.19-1.76
Education		
College Graduate (ref.)		
Post-Graduate Degree	1.19	0.96-1.48
Some College or Trade School	0.57**	0.44-0.72
High School or Less	0.51**	0.38-0.67
Country		
United States (ref.)		
Canada	0.72†	0.56-0.93
India	2.67**	2.05-3.49
United Kingdom	0.93	0.73-1.18
Brazil	1.62*	1.23-2.13
	† p<0.05	
	* p<0.01	
	** p<0.001	

Table 2: Chi-Square Tests Comparing Gender against Childcare and HouseworkResponsibility

	Women n(%)	Men n(%)	χ2
Housework			
Respondent			
Responsibility	798 (69)	455 (36)	(2)=157.1465**
Shared Responsibility	645 (49)	664 (51)	
Partner Responsibility	193 (33)	392 (67)	
Childcare			
No Children	658 (59)	452 (41)	(3)=186.0021**
Respondent			
Responsibility	400 (66)	205 (34)	
Shared Responsibility	434 (46)	507 (54)	
Partner Responsibility	144 (29)	347 (71)	
			'

† p<0.05 * p<0.01 ** p<0.001

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Can Performance and Representation Improve Public Perceptions of Police Legitimacy in Pursuing Domestic Violence Cases?

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Abstract

This paper explores how including women on police forces may improve outcomes for women and increase public perception of police legitimacy when addressing domestic violence. The theory of representative bureaucracy suggests that bureaucracies will be more responsive to the public and may garner additional legitimacy when they reflect the demographics of those they serve (Mosher 1968). This paper examines female representation in Kosovo, a country that has experienced ethnic conflict and gender violence and employs an experimental survey to understand how women rate police officers responding to domestic violence in the areas of trust, seriousness in carrying out investigations, and fairness. In the scenario where a respondent had little information about the policies of a force and could only see the demographic makeup of police, representation became an important influence for women on how they rated legitimacy of police in all areas. In the scenario where a policy was enacted that would benefit victims of domestic violence, performance mattered to both men and women for all three dimensions of legitimacy, whereas information on whether a man or woman enacted the policy had little impact. Implications of these findings are that if citizens know little about their police forces, representation becomes increasingly important. But even a less representative force can gain legitimacy by enacting effective policies that benefit less represented groups.

Keywords: gender, domestic violence, post-conflict, representation, policing

Gender equality is the fifth UN Sustainable Development Goal and includes ending all forms of discrimination and violence against women and girls in public and private settings (UN Women, 2022). Global research on 39 countries shows that having female police officers on a force is positively correlated with reports of sexual violence, and male and female victims report a preference for reporting to female officers (UN Women 2011). Studies suggest that female officers improve the quality of policing, increase rates of reporting and arrest for domestic violence, support affected citizens, help prevent escalation of domestic violence, and lead to declines in intimate partner homicide and rates of repeated abuse (Miller and Segal 2014; Meier and Nicholson-Crotty 2006; Andrews and Miller 2013; Jordan 2001; Sun 2007).

These findings point to a role of looking at domestic violence from a representative bureaucracy lens; bureaucracies may be more responsive to publics and garner additional legitimacy when they reflect the demographics of those they serve (Mosher 1968 and Krislov 1974). Passive representation, where the bureaucracy looks more like those they serve, can extend legitimacy to a public organization through a more symbolic role (Selden 1997) and may help communities

feel enfranchised when they see a bureaucrat who looks like them (Riccucci and Saidel 1997: Selden 1997; Thielemann and Stewart 1996, as referenced in Meier and Nicholson-Crotty 2006). Active representation, where representatives press for the interests of those they serve (Mosher, 1968), may increase public perceptions of legitimacy where bureaucrats share and act on values held by those they represent. Both passive and active representation are important to understanding legitimacy because while passive representation is a necessary but insufficient condition for active representation, each on its own may lead to different ends: passive representation may achieve demographic or symbolic representation as an end goal whereas active representation focuses on policy outcomes and implementation undertaken by those doing the representing (Meier and Nicholson-Crotty, 2006). This study addresses the need to examine representation in varied contexts by examining the role of passive and active gender representation in Kosovo, a country in the Balkans that has experienced gender-based violence during conflict. Its political context is interesting in that Kosovo is a young country established on ideals of gender representation in political, bureaucratic, societal, and cultural contexts (Constitution of the Republic of Kosovo, 2008). This context allows for a better understanding of how more equitable gender representation affects perceptions of legitimacy in post-conflict areas.

This chapter employs an experimental survey based on the work of Riccucci, Van Ryzin, and Lavena (2014) to understand how women and men living in post-conflict areas rate legitimacy of police officers in the areas of trust, seriousness in carrying out investigations, and fairness when there is passive and active representation. Respondents were asked to rate each of these dimensions of legitimacy for police forces with varying levels of gender representation and performance. In passive scenarios, female respondents rated units with higher female representation as more legitimate along each of the dimensions of legitimacy; for men, ratings only increased for how fair police are in carrying out investigations. Both men and women rated police units as more legitimate in the areas of how seriously they pursued investigations and how trustworthy they were while performance was not correlated with legitimacy in either group. In the active representation scenario, having a female in charge of a policy change was not correlated with higher ratings of police legitimacy among men or women, but higher performance was significant in all areas of legitimacy for both men and women.

Theoretical Framework

Representative bureaucracy is concerned with the proportional representation of populations in bureaucratic agencies, as well as with the impacts that representation has on policy making and implementation (Meier and Nicholson-Crotty 2006). Mosher (1968, 12) defines passive representation as "concern[ing] the source of origin of individuals and the degree to which, collectively, they mirror the society" and active as representation where the bureaucrat presses for the interests of those individuals whose interests they represent. The theory suggests that bureaucracies will be more responsive to publics and more accountable when they reflect the demographics of those they serve (Denhardt and deLeon 1995; Mosher 1968; Krislov 1974; Krislov and Rosenbloom 1981; Meier 1975; Selden 1997; Meier and Stewart 1992; Theobold and Haider-Markel 2008; Sowa and Selden 2003). Krislov (1974) suggested that the notion of

representation implies additional legitimacy as the smaller stands for and encapsulates the larger body represented.

Legitimacy and Values

One mechanism of representative bureaucracy discussed in the literature is the role of representation in relation to legitimacy (see Riccucci, Van Ryzin, and Lavena, 2014; Peters, Maravic, and Schroter, 2015; Gravier, 2013; Theobald and Haider-Markel, 2009). Researchers have found evidence that passive representation influences citizen perceptions of performance, trustworthiness, fairness, and legitimacy of police (Riccucci, Van Ryzin, and Lavena, 2014; Theobald and Haider-Markel, 2009; Riccucci, Van Ryzin, and Jackson 2018). Additionally, decisions that benefit the public can serve to legitimize the actions of government bureaucracies (Selden, 1997).

Citizen perceptions of legitimacy are increasingly important for countries that have undergone shifts in governance, borders, and ethnic conflict. The trust and confidence necessary to build community are broken down in societies that have been consumed by violence where neighbors prey on neighbors (Brinkerhoff, 2007). In areas where conflicts have occurred along ethnic and religious lines, these characteristics become particularly salient in future interactions with the state. Esman (1999, 365) emphasizes that the legitimacy of government in post-conflict areas is conditioned on seeing fellow ethnics wielding power at political levels and in state bureaucracies, being able to compete for and attain those positions, and providing "sympathetic hearing" and protection of allocation of services and provision of benefits.

Literature in the social sciences on legitimacy includes several conceptualizations of legitimacy: legitimacy as capturing beliefs that government power is exercised fairly in the interest of the whole nation (Levi and Sacks, 2009; Cromartie, 2018); as carrying out procedures correctly and fairly (Levi, Sacks, and Taylor 2009; Koppell, 2008; Scholte and Tallberg, 2018; Hurd, 2007; Tallberg and Zurn, 2019; Riccucci, Van Ryzin, and Lavena 2014); as justness measured through evaluations of appropriateness (Knox, 2016); as actions undertaken by government being seen as trustworthy (Parsons, 1960; Levi, Sacks, and Talyor 2009; Suchman 1995; Riccucci, Van Ryzin, and Lavena 2014); and as based on calculated self-interests of constituents of whether the organization's activities will benefit their group (Suchman, 1995). These underlying components of legitimacy can serve as proxies to understand legitimacy as a whole. Each concept highlights the importance of individual perceptions in evaluating legitimacy of the bureaucracy and indicates that public perceptions of legitimacy will be informed by personal values that have been formed within and shared across social groups. If bureaucrats mirror the demographic characteristics of those they serve, they are more likely to encompass their values and make decisions to benefit those they serve (Meier and Nigro 1976). When these values are espoused and applied to decision making, they may influence public perceptions of how procedures are carried out, how appropriate resulting actions are, and how fair and trustworthy bureaucrats are.

Legitimacy based on the actions of the bureaucracy can be divided into two types: performance legitimacy and procedural legitimacy. From the perspective of performance legitimacy, legitimacy is derived from government performance and effectiveness. Thus, states possess performance legitimacy in the eyes of citizens when they improve living standards in addition to filling state functions (Francois and Sud, 2006). It is related to collective gains, distributive justice, favorable outcomes, and fairness (Scholte and Tallberg, 2018; Hurd, 2007). Procedural legitimacy, on the other hand, embodies efficiency, expertise, impartiality, participation, accountability, problem solving, and correct procedure (Tallberg and Zurn, 2017; Scholte and Tallberg, 2018; Hurd, 2007). The emphasis on performance and procedural legitimacy justifies looking not only at citizen perceptions of legitimacy, but also at actions the state undertakes that may alter those perceptions.

The final aspect of legitimacy examined here is how legitimacy relates to values held by individuals. The foundation of legitimacy is based on justness and evaluations of appropriateness (Knox, 2016). These evaluations that lead to legitimacy have been described as "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Suchman, 1995, pg. 574). Citizen perceptions of legitimacy then will be informed by personal values that have been formed within and shared across their social groups. Thus, criteria for determining legitimacy will be based on values citizens hold.

Gender, Policing, and Representative Bureaucracy

Several researchers in representative bureaucracy have written about the importance of values and beliefs accounting for positive effects of representation. Background experiences and personal attitudes of civil servants are a key determinant of decision making, and partiality, shared values, beliefs, and empathic understanding are connected to representativeness; these shared values and beliefs lead to substantive results as minority bureaucrats articulate the interests of their group during decision-making processes (Van Riper, 1958; Lim 2006). Meier and Nicholson-Crotty (2006, 850) highlight that representative bureaucracy "assumes that shared experiences or values, which may not be shared across gender or race divisions, fundamentally affect the decisions made by and the actions taken by the bureaucrat." Active representation could affect perceptions of legitimacy based on citizen perceptions that the bureaucracy is acting on their behalf and pressing for their interests. Because the reflections of one's own values is inherent to legitimacy, a potential mechanism for building legitimacy is likely through representation as residents interact with bureaucracies when interfacing with the government.

Researchers have looked at both gender and policing extensively with the representative bureaucracy literature (Meier and Nicholson-Crotty, 2006; Keiser et al. 2002; Riccuci, Van Ryzin, and Lavena, 2014; Andrews and Miller, 2013). Keiser et al. (2002) discussed three types of issues where gender representation is likely to occur: (1) policies that benefit women as a class; (2) policies that through the political process have been defined as gendered and may therefore be more salient to women; and (3) instances where gender fundamentally changes the relationship with the client. In the area of policing, the importance of female representation has been shown

in the US and England. Gender representation on police forces influences perceived job performance, trustworthiness, and fairness; greater numbers of women on police forces leads to higher rates of reporting rape and processing rape cases; and female police chief constables are associated with higher arrest rates for domestic violence though an increase in female police officers is only significant when they are able to carry out front-line police work (Riccucci, Van Ryzin, and Lavena, 2014; Andrews and Miller, 2013; Schuck, 2018; Nicholson-Crotty et al. 2018).

Meier and Nicholson-Crotty (2006) suggest four theoretical reasons a police force with more female officers may lead to better outcomes in issues affecting women: (1) a woman who sees more women on a force could assume sexual assault is taken more seriously; (2) a woman will be more likely to have a female officer as first point of contact; (3) female officers may sensitize their male colleagues; and (4) a female officer could share a set of values with female residents because of common gender-related experiences. Note that only the final reason directly depends on the actions of an officer representing her group; the others involve others' perceptions (either the perception of those reporting or of male officers after interacting with female officers). As such, the authors note that in two of these mechanisms, there does not need to be contact between a citizen and a female officer for representation to occur: (1) female clients may observe more women patrolling in their city, and (2) female officers may share a set of values with other women.

Because the gender of police officers should be more salient to those who are usually underrepresented, women may care more about female representation on police forces than their male counterparts, which would lead them to rate officers as being more legitimate along the three dimensions discussed above. This leads to the following hypotheses:

H1: Women will rate units with higher levels of gender representation as more legitimate

H2: Women's ratings of bureaucrat's legitimacy will increase further when a female bureaucrat is seen actively pursuing the interests of their group

Representation may not be the only factor in citizen's evaluations of bureaucratic legitimacy. Literature on representative bureaucracy implies that representation improves performance, whether directly or indirectly, through impact on bureaucrat's decisions or citizen perceptions (Andrews et al., 2016). However, representation is likely not the only factor influencing good performance. Research on police performance indicates that factors like psychological and physiological stress responses and training in a variety of methods impact police performance positively or negatively (Andersen and Gustafsberg, 2016; Arnetz, Arble, Backman, Lynch, & Lublin, 2013; Arnetz, Nevedal, Lumley, Backman, & Lublin, 2009). As such, performance itself can influence perceptions of legitimacy outside of performance gains that are driven by representation. This leads to the following hypothesis:

H3: Women will rate units with higher levels of performance as more legitimate when controlling for levels of representation

Research has explored whether there is an interaction effect between representation and performance. Riccucci, Van Ryzin, and Lavena (2014) explore whether citizens more positively evaluate an agency when there is both high representation and high performance and find that while both matter separately, there does not seem to be an interaction between representation and performance in their context. Riccucci, Van Ryzin, and Jackson (2018) find that the interaction between representation and performance is not significant for black respondents, though it is for white respondents. These studies indicate that performance and representation are significant separately, but that the interaction of the two is not consistent across groups.

Kosovo Context: Domestic Violence

From its inception as a nation, leaders of Kosovo have identified gender representation as a value and tool for more effective government. The 2008 constitution and subsequent civil service laws recognize the need for equal opportunities for men and women (Constitution of the Republic of Kosovo, 2008; Law on Civil Service, 2010). Increasing gender representation on police forces is a prominent area of focus for improving the civil service in Kosovo and has been an aim of the Organization for Security and Cooperation in Europe (OSCE), which has supported the Association of Women in the Kosovo Police since 2004 (OSCE, 2019). A 2018 campaign featured female KP officers, retired American Chief of Police, and the U.S. Embassy's Department of Justice police support program (ICITAP) encouraging women to join the police force (U.S. Embassy Pristina, 2018). However, in 2017 women remained underrepresented and made up only 14% of the 8,820 Kosovo Police, including constituting 11% of uniformed officers (Farnsworth et al., 2018). In 2019, out of the 430 KP officers hired to go to basic training, 30.9% were female; additionally, a 2019 mandate required 30% of participants at trainings to be female (Jones 2020).

Responding to domestic violence has been another focus of the Kosovo Police. Progress in the legal framework for addressing domestic violence was made in 2018, when the Criminal Code was revised to define and treat domestic violence separate from other offenses; in 2019, 650 more cases were reported than in 2017 (UN Women 2019). Failing to comply with a civil court judgment on domestic violence is considered a criminal and prosecutable offense, though prosecution is rare (US Department of State, 2019).

Police data in Kosovo indicate 94% of gender-based violence is perpetrated by men, and 62% of Kosovars have experienced domestic violence (68% of women and 56% of men) (*ibid.*). In 2017, of the 1,125 cases of reported domestic violence, 76% of the victims were women (*ibid.*). Police are often the first to respond to domestic violence calls, and while 73.6% of Kosovars say they would turn to the police to assist with domestic violence, many do not trust officers to follow through with investigations (UN Women 2017). Female police are actively working to change the culture of normalizing and dismissing domestic violence cases (*ibid.*). In a training for Kosovo Police, Jane Townsley, founder of Force International, retired UK senior police officer, and experienced gender specialist in the field of policing and security, emphasized the importance of domestic violence units, trust and confidence in police, gender-responsive policing, and effective policies. She noted that "effective police response is a major contributing factor to the reputation of Kosovo Police" (UN Women 2018).

Despite institutionalized values of representation, sexual violence is still a concerning issue in Kosovo. Research conducted by Human Rights Watch found that rape and other forms of sexual violence were used as "weapons of war and instruments of systematic ethnic cleansing" during the conflict with Serbia (Human Rights Watch, 2000). Much of this violence occurred as police officers joined military groups in carrying out actions against the general population. Unfortunately, sexual violence has not been limited to the conflict. Recent statistics reported by the Kosovo Women's Network indicate that more than two-thirds of women have been victims of domestic violence, and women's rights groups in Kosovo report that workplace sexual harassment and abuse often go unreported for fear of dismissal or retaliation (US Department of State, 2019). A high-profile domestic violence case in 2018 that resulted in the murder of the perpetrator's wife and nine-year-old daughter sparked public protests, as the victims' relatives claimed they contacted Kosovo Police (KP) multiple times to request assistance, including reporting a death threat four hours before the murder. The murderer was later found guilty and sentenced to 24 years in prison (US Department of State, 2019). In February 2019, Kosovo women protested outside Kosovo Police Headquarters in Pristina after a teenager reported to police that she had been raped by a teacher; she was then assaulted by the Kosovo Police Officer to whom she reported and was forced to have an abortion (Surk, 2019). The Kosovo Police Inspectorate reported that 11 police officers were accused of domestic violence in 2019 and nine in 2020 (Ahmeti 2021).

The focus on institution-building, increasing the number of women on the police force, and continued salience of sexual violence in Kosovo, make this an appropriate area to research whether increased numbers of women on police forces, women in positions of authority to make policy choices, and enhanced performance lead to increased perceptions of legitimacy.

Data

The data for this chapter come from an experimental survey administered in Kosovo in September 2019. Participants rated trust, fairness, and performance of Kosovo Police in both a passive representation and active representation scenario involving domestic violence. In the passive scenario participants were randomly assigned a ratio of male to female police officers of either 9:1 or 5:5 for a police force that receives calls reporting domestic violence, conducts investigations, and makes determinations for which actions should be taken. Participants were also randomly assigned a police performance measure of 70% or 30% arrests and were told that arrests reduce the number of victims seriously injured or killed due to domestic violence. These numbers were chosen to indicate low and high representation and poorer and higher performance and are based on a similar experiment from Ricucci, Van Ryzin, and Lavena (2014); the researchers chose these values based on several cognitive pretests found to be salient on both gender and performance factors. After reading the scenarios, respondents were asked to rate how seriously police pursue an investigation, how much of the time citizens can trust police in the scenario to do what is right, and how fair they would say police are likely to be in handling domestic violence cases.

For the active scenario, the same participants were then randomly assigned to a scenario where either a male or female had been promoted to oversee the handling of domestic violence cases. They were told the officer implemented a new system where victims of domestic violence meet with officers of their own gender to report the crime, and it is now mandatory to arrest perpetrators of domestic violence. They were then randomized into a group where domestic violence decreased by either 80 or 20 percent and told victims reported they feel more comfortable reporting domestic violence crimes to police. These thresholds are also based on research by Riccucci, Van Ryzin, and Lavena (2014). Respondents were again asked to rate how seriously police pursue an investigation, how much of the time citizens can trust police in the scenario to do what is right, and how fair they would say police are likely to be in handling domestic violence cases.

Because respondents were first assigned to passive and then to the active scenario, there should not be any influence from the active scenario on the passive; however, respondents could have been influenced by the passive scenario when answering questions about the active scenario. To ensure this was not the case, ratings of how seriously police pursue investigations, trust, and fairness in the active scenario were regressed on assignment to both passive representation and performance. Neither passive assignment variable was significant, indicating that exposure to the passive scenario did not influence ratings in the active scenario.

Randomization in each scenario meant all participants were assigned to one of four possible groups for both the passive and active scenarios, as shown in figures one and two.

Group 1: Low Representation, Low Performance (N=87) Kosovo Police in Qytet/Grad receive calls reporting domestic violence, conduct investigations of these crimes, and make determinations as to what actions should be taken. The officers assigned to this city include 9 men and 1 woman. According to a recent assessment, the police in Qytet/Grad made a mandatory arrest of the batterer in 30% of cases . Evidence shows that making such arrests reduces the number of victims seriously injured or killed as a result of domestic	Group 2: Low Representation, High Performance (N=112) Kosovo Police in Qytet/Grad receive calls reporting domestic violence, conduct investigations of these crimes, and make determinations as to what actions should be taken. The officers assigned to this city include 9 men and 1 woman. According to a recent assessment, the police in Qytet/Grad made a mandatory arrest of the batterer in 70% of cases. Evidence shows that making such arrests reduces the number of victims seriously injured or killed as a result of domestic violence.
injured or killed as a result of domestic	domestic violence.
violence.	

Figure 1: Domestic Violence Randomization (Passive)

Group 3: High Representation, Low	Group 4: High Representation, High
Performance	Performance
(N=125)	(N=120)
Kosovo Police in Qytet/Grad receive calls	Kosovo Police in Qytet/Grad receive calls
reporting domestic violence, conduct	reporting domestic violence, conduct
investigations of these crimes, and make	investigations of these crimes, and make
determinations as to what actions should be	determinations as to what actions should be
taken. The officers assigned to this city	taken. The officers assigned to this city include
include 5 men and 5 women .	5 men and 5 women .
According to a recent assessment, the police	According to a recent assessment, the police in
in Qytet/Grad made a mandatory arrest of	Qytet/Grad made a mandatory arrest of the
the batterer in 30% of cases . Evidence	batterer in 70% of cases. Evidence shows that
shows that making such arrests reduces the	making such arrests reduces the number of
number of victims seriously injured or killed	victims seriously injured or killed as a result of
as a result of domestic violence.	domestic violence.

Figure 2: Domestic Violence Randomization (Active)

Group 1: Low Representation, Low	Group 2: Low Representation, High
Performance	Performance
(N=132)	(N=111)
Recently in Qytet/Grad, a male officer was	Recently in Qytet/Grad, a male officer was
promoted to oversee handling of domestic	promoted to oversee handling of domestic
violence cases. This officer implemented a	violence cases. This officer implemented a
new system where victims of domestic	new system where victims of domestic
violence meet with officers of their own	violence meet with officers of their own
gender to report the crime, and it is now	gender to report the crime, and it is now
mandatory to arrest perpetrators of domestic	mandatory to arrest perpetrators of
violence.	domestic violence.
Rates of domestic violence have decreased	Rates of domestic violence have decreased
by 20% in the city, with victims saying they	by 80% in the city, with victims saying they
feel more comfortable reporting domestic	feel more comfortable reporting domestic
by 20% in the city, with victims saying they feel more comfortable reporting domestic violence crimes to police.	by 80% in the city, with victims saying they feel more comfortable reporting domestic violence crimes to police.

Group 3: High Representation, Low Performance (N=112) Recently in Qytet/Grad, a female officer was promoted to oversee handling of domestic violence cases. This officer implemented a new system where victims of domestic violence meet with officers of their own gender to report the crime, and it is now mandatory to arrest perpetrators of domestic violence. Rates of domestic violence have decreased by 20% in the city, with victims saying they feel more comfortable reporting domestic violence crimes to police.	Group 4: High Representation, High Performance (N=135) Recently in Qytet/Grad, a female officer was promoted to oversee handling of domestic violence cases. This officer implemented a new system where victims of domestic violence meet with officers of their own gender to report the crime, and it is now mandatory to arrest perpetrators of domestic violence. Rates of domestic violence have decreased by 80% in the city, with victims saying they feel more comfortable reporting domestic violence crimes to police.
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The survey was given to a representative sample of all ethnic communities and equal numbers of men and women from the 38 major municipalities in Kosovo ages 18 and up (N=490). Weighting was introduced to the sample by multiplying the minorities by a factor of 2.41 for every one Albanian.⁹ This ensured 50 Serbian respondents and 50 respondents from other minorities. Responses were weighted accordingly in all analyses. The sampling method used is a multistaged random probability method (typical of surveys in Kosovo). Stage one accounts for the appropriate rural/urban divide (45% urban/55% rural) of the country. Stage two refers to selecting households using a random-house technique. This consists of an assigned starting point in a given direction. In urban areas, the selected household is every third apartment, counting from the top floor in each entrance. In rural areas, the selected household is every third inhabitable dwelling on both sides of the interviewer's route. Stage three selects one member of the household using the nearest birthday technique. Stage four accounts for substitution of a respondent after two attempts (one initial visit and one call back).

Table 1 below shows the descriptive statistics for assignment to the passive representation domestic violence scenario while Table 2 shows descriptive statistics for the active representation domestic violence scenario. Approximately 52% of all respondents are female, 89% are Albanian, and 5% are Serb (before weighting, this was 61% Albanian and 18% Serb).¹⁰ The average monthly income is 648 Euros and the average age is 36. All models control for gender (female=1; male=0), age (a continuous variable), marital status (married=1; else 0), ethnicity (defined as Serb, Albanian, and other), administrative district (7 dummy variables indicating district the respondent resides in), education (a categorical variable with six categories where 6th-9th grade

⁹ Analyses were conducted without weighting and found similar results.

¹⁰ Kosovo statistics show 92.9% of the population are Albanian, and 1.5% are Serb. However, these estimates may under-represent Serb and some other ethnic minorities because they are based on the 2011 Kosovo national census, which excluded northern Kosovo (a largely Serb-inhabited region) and was partially boycotted by Serb and Romani communities in southern Kosovo (CIA, 2020).

is the lowest category and doctorate is the highest), and monthly income (ranging from less than 400 Euros/month to over 1000 Euros/month).

Variable	Low Rep/Low Perf	Low Rep/High Perf	High Rep/Low Perf	High Rep/High Perf	Total	Total Percentage
# of						
Respondents	95	123	136	136	490	100%
Gender						
Female	52	54	72	77	255	52%
Male	43	69	64	59	235	48%
Ethnicity						
Serb	3	7	9	7	26	5%
Albanian	88	112	117	118	435	89%
Other	4	4	10	11	29	6%
4						
Aye	11	10	0	0	40	00/
	14	12	0	9	43	9%
20-24	20	34	21	30	105	Z1%
25-34	23	29	41	32	120	20%
35-44	12	19	20	28	80 04	17%
40-04	9	10	23	19	01	12%
55-59	10	0	10	10	30	7 % 20/
60-64	3	4	6	4	17	3%
65-74	0	0	1	4	11	2% 40/
75-84	3	1	0	0	4	1%
Education						
6th-9th	5	9	13	15	42 47	9%
10th-13th	30	33	34	29	126	26%
Associates	12	25	17	19	73	15%
Bachelors	32	<u>-</u> 0 46	48	54	180	37%
Masters	15	9	22	19	65	13%
PhD/MD	0	0	2	0	2	0%
	.	~	-	.	-	0,0
Marital						
Single/Divorced	48	51	59	69	227	46%
Married	47	72	77	67	263	54%

Table 1. Descriptive Statistics for Passive Scenario by Group

Monthly Incom	e (Euros)						
<400	21	29	35	36	121	25%	
400-700	40	45	52	45	182	37%	
700-1000	20	20	28	39	107	22%	
>1000	13	28	22	17	80	16%	

Table 2. Descriptive Statistics for Active Scenario by Group

Variable	Low Rep/Low Perf	Low Rep/High Perf	High Rep/Low Perf	High Rep/High Perf	Total	Total Percentage
# of						
Respondents	132	111	112	135	490	100%
Gender						
Female	79	52	62	63	256	52%
Male	53	59	50	72	234	48%
Ethnicity						
Serb	7	6	8	6	27	6%
Albanian	118	100	97	121	436	89%
Other	8	6	6	9	29	6%
Age						
Under 20	14	7	13	11	45	9%
20-24	29	26	26	26	107	22%
25-34	34	33	31	28	126	26%
35-44	21	21	18	24	84	17%
45-54	12	14	13	22	61	12%
55-59	13	5	7	10	35	7%
60-64	6	2	1	8	17	3%
65-74	4	2	3	3	12	2%
75-84	0	1	0	3	4	1%
Education						
6th-9th	10	9	6	16	41	8%
10th-13th	35	25	24	42	126	26%
Associates	22	21	17	14	74	15%
Bachelors	53	39	45	43	180	37%
Masters	12	17	19	18	66	13%
PhD/MD	0	0	1	1	2	0%

Mantai						
Single/Divorced	75	51	59	62	247	50%
Married	57	60	53	73	243	50%
Monthly Income (Euros)					
<400	34	28	29	30	121	25%
400-700	42	49	37	55	183	37%
700-1000	34	24	20	27	105	21%
>1000	22	11	26	23	82	17%

Balance tests were carried out using a t-test to ensure randomization occurred. For the passive representation scenario, respondents were first randomized into a representative or non-representative group. No characteristics were significant except for age. For the assignment to high or low performance for the passive scenario, t-tests were not significant except for marital status. For the active scenario, all characteristics were not significant for the random assignment to higher and lower representation. For the performance assignment for the active scenario, only gender was significant. Non-significant results of the t-test indicate that proper randomization occurred (see Appendix A).

The dependent variables in this study capture components of procedural legitimacy: 1) how seriously police pursue investigations, 2) how often they can be trusted to do the right thing, and 3) how fair police are in handling investigations. Seriousness in pursuing investigations is strongly correlated with trusting police to do the right thing (both passive and active scenarios r=0.8), and fairness in handling investigations is moderately correlated with both seriousness and trust (passive: r=0.5 for both; active: r=0.7 for both) (see Appendix A Tables 5 and 6 for correlation tables). These correlations indicate overlap in the concepts being measured and represent a potential weakness in the current study. Each of the dependent variables are rated using a five-point Likert scale. The main explanatory variables of interest are the two assignment groups respondents were randomly assigned to: how representative the police force is of the population and high or low police performance. Additional controls include respondent age, gender, marital status, municipality, and education.

All analyses below report coefficients of linear regressions. Ordinal logits were also performed as a robustness check and the same variables were found to be significant in both models. All models were run with interactions between the two assignment variables, and the interactions were not significant in any models. These interactions were dropped in subsequent analyses.

Findings

Marital

Hypothesis one stated that women will rate units with higher levels of gender representation as more legitimate. As reported in Table 3 below, women who were assigned to the more representative group were more likely to give police higher ratings for how seriously they carried out investigations (p<0.05), how much they trusted police to do the right thing (p<0.05), and how

fair they were in handling investigations (p<0.001). The same assignment is not significant among male respondent for how seriously police pursue investigations and trusting police to do the right thing (p=0.24 and 0.22 respectively). However, being assigned to a more representative police force is correlated with men having higher perceptions that police handled investigations more fairly (p<0.10).

	Passiv	е			
		St	P-		
	Coeff	Error	Value	R ²	Ν
Seriously Pursue					
Investigation					
Females	0.329	0.164	0.046	0.179	246
Males	0.248	0.169	0.143	0.173	244
Trust Police to Do the Right					
Thing					
Females	0.307	0.151	0.043	0.171	246
Males	0.227	0.166	0.172	0.138	244
Fairness in Handling					
Investigations					
Females	0.634	0.170	0.000	0.167	246
Males	0.487	0.182	0.008	0.140	244

Table 3 Effects of a More Re	presentative Police Force	on Percentions	of Logitimacy
Table 5. Effects of a more Re	presentative Police Force	on Perceptions	or Legitimacy

This suggests that, for women, a more representative police force increases perceptions in all three aspects of legitimacy while it only impacts men's perceptions in the area of fairness. Men may see women as being more fair, but this does not translate into perceptions that the work on the case (carrying out the investigation and trusting that they will do the right thing) will be impacted. Notably, the coefficients for fairness are higher for men and women than the other two aspects of legitimacy. Since trust and seriousness are more closely correlated, it is consistent with men reacting similarly to these measures.

Hypothesis two states that women will rate units with higher levels of gender representation as more legitimate when bureaucrats actively pursue the interests of their group. In this experiment, this means women should rate units with a female officer overseeing domestic violence efforts as more legitimate. However, Table 4 below shows that neither men nor women being assigned to a group where a woman is promoted to lead domestic violence efforts is consistently correlated with increases in ratings of police officers. The only exception is for females in their ratings of trusting police to do the right thing (p<.10 in both cases). The scenario only differed between whether a woman or man put an effective policy in place. Regardless of gender, the outcome was

the same. This may point to the importance of how effective the policy was rather than the gender of the officer establishing the policy and is addressed in hypothesis three below.

	Active				
	Coeff	St Error	P-Value	R ²	Ν
Seriously Pursue					
Investigation					
Females	0.192	0.169	0.258	0.268	246
Males	0.238	0.167	0.154	0.182	244
Trust Police to Do the Right					
Thing					
Females	0.257	0.154	0.096	0.278	246
Males	0.120	0.165	0.471	0.149	244
Fairness in Handling					
Investigations					
Females	0.054319	0.169589	0.749	0.1651	246
Males	0.184835	0.152254	0.226	0.1513	244

Table 4. Effects of a Female Enacting a Policy on Perceptions of Legitimacy

Finally, hypothesis three states that women will rate units with higher levels of performance as more legitimate. Table 5 below shows that being assigned to a group with higher performance is significantly and positively correlated with perceptions of seriousness in pursuing investigations and trusting police to do the right thing in the scenario where respondents only know the demographic makeup of police but no policy is discussed (the passive representation scenario) (p<0.001). It is not significant for perceptions of fairness in handling investigations for either men or women. This again shows a consistency in correlation between seriousness and trust.

Table 5. Effects of Higher Performance on Perceptions of Legitimacy										
	Passive	;				Active				
								P-		
		St	P-				St	Valu		
	Coeff	Error	Value	R ²	Ν	Coeff	Error	е	R ²	Ν
Seriously										
Pursue										
Investigation										
							0.16		0.26	24
Females	0.839	0.164	0.000	0.179	246	1.124	7	0.000	8	6
							0.16		0.18	24
Males	0.776	0.171	0.000	0.173	244	0.668	4	0.000	2	4

Trust Police to Do the Right Thing										
							0.15		0.27	24
Females	0.747	0.158	0.000	0.171	246	1.059	2	0.000	8	6
							0.16		0.14	24
Males	0.658	0.167	0.000	0.138	244	0.570	9	0.001	9	4
Fairness in Handling										
Investigations										
	0.000	0 474	0.000	0.407	040	0.004	0.17		0.16	24
Females	0.223	0.174	0.202	0.167	240	0.824	2	0.000	5	6
	0.257	0 170	0 122	0 1 4 0	244	0.277	0.16	0.096	0.15	24
Males	0.207	0.170	0.132	0.140	244	0.277	1	0.000	1	4

Interestingly, performance matters for men and women in the case where a policy is put into place to improve handling of domestic violence cases in all areas of legitimacy (note: p<0.001 for all except males in their perception of fairness in handling investigations, which is significant at the p<0.10 level). This indicates that performance is more important than gender of the officer establishing the policy, and that an effective policy at leads to increased performance is tied to increased perceptions of all types of police legitimacy.

Research Implications and Limitations

This study contributes to the literature on representative bureaucracy by highlighting the different roles representation and performance play in how respondents rate the legitimacy of police in passive and active representation scenarios in a post-conflict setting. Findings are similar to those in other countries: the representation of women is correlated with higher ratings of legitimacy for women. In the passive representation scenario, where a respondent had little information about the policies of a force and could only see the demographic makeup of police, representation became an important influence on legitimacy for women in each of the dimensions of procedural legitimacy. Increasing the number of women on a force increased their ratings of how seriously police pursue investigations, how much they trusted them to do the right thing, and how fair police are in handling investigations. In contrast, knowing the demographic makeup of the force only influenced men's perceptions that cases would be carried out in terms of seriously pursuing an investigation and being trusted to do the right thing. This suggests that both men and women associate women with fairness, but that it is shared values and lived experience of women that influence ratings of seriousness and trust, as theorized by existing literature.

Interestingly, performance was significantly correlated with higher ratings for men in the areas of legitimacy where representation did not influence them; namely, men rated seriousness in pursuing an investigation and trusting police to do the right thing when there was higher

performance but not higher representation, and performance was not significant for men in rating how fair police are, though representation was significant to this rating of fairness. For men in scenarios where only demographic information is known and no policy positions have been stated, representation and performance seem to be markedly separate, perhaps suggesting distinct associations with the various aspects of legitimacy, with seriousness and trust on the one hand and fairness on the other. Literature on leadership indicates that fairness is seen as a more stereotypically female trait and that may be playing out in evaluations here (Bruckmüller and Branscombe, 2010). This is affirmed by higher correlations between seriousness and trust and lower correlations of those concepts with fairness. Because fairness seems to be markedly female, it is unsurprising that both men and women think increasing female representation on the force would increase fairness of that force's response to domestic violence. Seriousness in carrying out an investigation and trusting police to do the right thing may be seen as tied to outcomes of an investigation, whereas fairness may be seen as more intrinsically related to how women treat other women.

Local context may also play into these findings. One study found that respondents felt a need for improved inter-institutional cooperation. One respondent said, "Institutions don't know their obligations, they send victims from one institution to another and re-victimize them in this way because they have to tell their story over and over again" (Kosovo Women's Network 2015, p. 315.). Perhaps even if police are seen as being fair, there is a perception that a case will still not come to the "right" conclusions, harming perceptions of trustworthiness and how serious police pursue investigations. There may be little hope for a positive outcome if coordination between institutions does not occur. Further research is warranted.

Turning to the active representation scenario, where a policy was enacted that would benefit victims of domestic violence, performance mattered to both men and women for all three dimensions of legitimacy, whereas information on whether a man or woman enacted the policy had little impact. Respondents seem to care more about the potential outcome of a policy being in place than they do about who is responsible for making the change. This could point to the importance of representation when there is little information on how a force carries out their responsibilities and the only information available to evaluate the force on is whether women are present. However, when an effective policy is put into place, and this is known, respondents can rely on that information to rate officers. Implications of this finding are that if citizens know little about their police forces, representation becomes important. But even a less representative force can gain legitimacy by enacting good policies that benefit less represented groups.

Passive representation may be a means of allowing the under-represented to feel enfranchised, while active representation seeks to put into place policies that benefit under-represented groups. More research should be carried out on how passive and active representation may differ in their end goals and what influences those perceptions, and on how dimensions of legitimacy differ from one another, including whether some aspects of legitimacy are more inherently gendered. Further research on intensity of doses and threshold effects could also be beneficial to understanding representation, performance, and interactions between the two.

Conclusion

While representative bureaucracy has been studied in a variety of policy areas in the US, little research has been done on citizen perceptions of legitimacy in post-conflict areas. This article used an experimental survey to understand how respondents react to more or less representative police forces and higher and lower performance. In passive scenarios, female respondents rated units with higher female representation as more legitimate along each of the dimensions of legitimacy; for men, ratings only increased for how fair police are in carrying out investigations. Both men and women rated police units as more legitimate in the areas of how seriously they pursued investigations and how trustworthy they were, while performance was not correlated with legitimacy in either group. These findings may support other research that victims of domestic violence will benefit from female police officers. Studies that suggest better outcomes, higher reporting, and more outreach to women are confirmed here by perceptions that female officers can be trusted to do the right thing, will handle cases fairly, and be serious in carrying out investigations. More research should be done in other post-conflict areas and in Kosovo to better understand how representation and performance influence the various dimensions of legitimacy to understand their potential and differing uses as tools for building legitimacy.

Appendix A

ocenano						
	Group	1	Group	2	Т-	P-
	Mean		Mean		value	Value
Age (Continuous)	35		37.81		-2.09	0.04
Age	3.46		3.81		-2.13	0.03
Gender (male=1)	0.53		0.48		1.21	0.23
Marital Status	1.56		1.60		-0.92	0.36
Ethnicity	2.63		3.05		-1.81	0.07
Education	3.10		3.01		0.79	0.43
Monthly Income	2.14		2.12		0.29	0.77
Municipality	20.07		19.20		0.85	0.39
Citizenship (y/n)	0.97		0.98		-0.97	0.33
Ethnicity (three						
groups)	1.50		1.72		-3.03	0.00
Serb (y/n)	0.19		0.20		-0.47	0.64
Albanian (y/n)	0.66		0.54		2.69	0.01

Table I. Balance Test for Representation in Passive DVScenario

Table II. Balance Test for Performance in Passive DVScenario

	Group	1	Group	2	Т-	P-
	Mean		Mean		value	Value
Age (Continuous)	37.14		36.03		0.82	0.41
Age	3.71		3.60		0.67	0.50

0.49	0.51	-0.31	0.76
1.64	1.54	2.03	0.04
2.83	2.88	-0.23	0.82
3.14	2.97	1.53	0.13
2.16	2.11	0.54	0.59
18.90	20.20	-1.28	0.20
0.98	0.97	0.39	0.70
1.62	1.63	-0.11	0.91
0.19	0.20	-0.41	0.68
0.60	0.59	0.26	0.79
	0.49 1.64 2.83 3.14 2.16 18.90 0.98 1.62 0.19 0.60	0.490.511.641.542.832.883.142.972.162.1118.9020.200.980.971.621.630.190.200.600.59	0.490.51-0.311.641.542.032.832.88-0.233.142.971.532.162.110.5418.9020.20-1.280.980.970.391.621.63-0.110.190.20-0.410.600.590.26

Table III. Balance Test for Representation in Active DV Scenario

	Group 1	Group 2		
	Mean	Mean	T-value F	P-Value
Age (Continuous)	36.3012	36.79249	-0.36566 0).714776
Age	3.630522	3.667984	-0.22948 0).818587
Gender (male=1)	0.496032	0.505976	-0.2226 0).823941
Marital Status	1.593074	1.575	0.363602 0).716319
Ethnicity	2.869048	2.849802	0.083955 0).933126
Education	3.04065	3.056	-0.13341 0).893921
Monthly Income	2.114173	2.145669	-0.35379 0).723643
Municipality	19.33071	19.85433	-0.51258 0).608467
Citizenship (y/n)	0.971193	0.979675	-0.60508 0).545406
Ethnicity (three				
groups	1.606299	1.637795	-0.43603 0	0.663004
Serb (y/n)	0.188976	0.204724	-0.44554 0).656117
Albanian (y/n)	0.602362	0.57874	0.540455 0).589121

Table IV. Balance Test for Representation in Active DV Scenario

	Group 1	Group 2		
	Mean	Mean	T-value F	P-Value
Age (Continuous)	35.688	37.40278	-1.27823 0	0.201763
Age	3.544	3.753968	-1.28831 0).198234
Gender (male=1)	0.456	0.545455	-2.01029).044936
Marital Status	1.536481	1.630252	-1.89365 0	0.058886
Ethnicity	2.984064	2.73622	1.082418 0).279585
Education	3.146341	2.952	1.694011 0	0.090894
Monthly Income	2.170635	2.089844	0.908115 0).36425
Municipality	20.0754	19.11719	0.938551 0).348409
Citizenship (y/n)	0.979339	0.97166	0.547779 0).584095
Ethnicity (three				
groups	1.638889	1.605469	0.462659 0).643808
Serb (y/n)	0.218254	0.175781	1.203083 0).229507

Albanian (y/n) 0.571429 0.609375 -0.86856 0.385502

Table V. Correlations

Gender (Passive)

 Serious
 Trust
 Fair

 Serious
 1
 1

 Trust
 0.8004
 1

 0
 0
 1

 Fair
 0.5140
 0.5411
 1

 0
 0
 0
 1

Gender (Active)

	Serious	Trust	Fair
Serious	1		
Trust	0.8393	1	
	0		
Fair	0.6580	0.6651	1
	0	0	

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Gender Disparities in Educational Attainments: Does Gender Gaps Matter?

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Abstract

In today's globally competitive environment, educational attainment plays an important role from empowerment of the communities to sustain the higher growth. However, in a society as deeply stratified as India, disparities in education within social groups can be observed through various distributions, such as religion, caste, and gender, among others. In this paper, we empirically examineeducational enrolment functions and conditions of enrolment within marginalized groups. The mixed methodology is used for collecting empirical data through extensive field work carried out in western districts of India's most populated province known as 'Uttar Pradesh'. Further, the gender difference ineducational attainment is decomposed within social groups to understand the individual factors most responsible for the differential treatment. The findings describe that within disadvantaged groups, a consistent feature is widespread gender disparity in educational attainment for uncleaned occupational scheduled caste girls. Apart from economic factors, the analysis describes that the treatment of sons and daughters by parents is a potential explanation of the gender gap in education in India. Therefore, the persistent of such gender based discrimination in household expenditure on education has caused lot of challenges not only to achieve in educational attainment for girls in one of the largest province of world 2nd most populous country but also in mitigating the widening of global gender gaps in way to achieve the sustainable development goals (SDGs).

Keywords: Educational attainments, Gender Gaps, Decomposition Analysis, SDGs, India

Introduction

In 2015, the UN adapted seventeen Sustainable Development Goals (SDGs) that all countries including India pledged to reach by 2030. In development context, the importance of early school education has been recognized as a fundamental human value that virtually contributes to the success of every single development goal. Better early school educational attainments not only helpin containing the poverty and inequality but also helps in better nurturing, access to quality higher education, health, employability skills and protection etc. In this context, India, a country of world's youngest population where millions of youth continue to join labour force every year in coming decades, their access to early school and educational achievements hold the key to meet demographic dividend and inclusive cum sustainable goals. Looking an urgency to enhance human capital to contain both poverty and inequality, this empirical piece of research paper is an attempt to critically examine the gender and social equality in children continuing education from poor households currently engaged in unclean occupation in urban areas of India's most populist state of Uttar Pradesh. The research focuses on a 360 degree perspective of the complex socio-

economic- polity environment to not only look at employability but also youth and gender specific employment aspirations, requirements and interest that are neither in education, employment and training (NEET). Thus the paper illustrates some of the key problems and related gaps to remove bottleneck for youths, especially girls and boys from poor, marginalized and vulnerable section of the society in access to quality education, employability and future employment. Most importantly, the analysis of the paper emphasizes on urgent attentions of the policy makers and implementers to focus on four core challenges (4E) of education, equality, employability, and employment that is decent and more productive especially in the most populous state of Uttar Pradesh if the country has to reap the demographic dividend.

Tracking both policies and outcomes is essential in order to analyse and determine the relative effectiveness of different approaches, thereby providing policymakers with the tools to plan and allocate resources to make optimal choices while ensuring equal access and opportunity for all youth irrespective of their caste, class, gender and religion etc. such interventions will help in achieving theSustainable Development Goals (SDGs,2015).

Some Facts about the Universe of the Study



Source: www.google.co.in/ Uttar Pradesh

The province of Uttar Pradesh is not only one of the most populous states in India but the region is also the most populous country subdivision in the world. Uttar Pradesh, with a total area of 243,290 square kilometers (93,935 sq mi), is India's fourth-largest state in terms of land area and is roughly of same size as United Kingdom. The literacy rate in the state has gone up in recent years and yet continues to remain at about 70 per cent which is below the national average of 74 per cent. Its population forms 16.50 per cent of India's total population in 2011 (GOI/Census, 2011). Over the years, there has been a continuous migration of people from rural and semi-urban areas to towns andcities and thus the number of class I cities and class II cities have increased. In Uttar Pradesh, two cities were selected for the study; these are Ghaziabad City (Class I) and Mathura City (Class II). Both the cities are also part of National Capital Region (NCR) mega urban agglomeration.

Significance of education can be drawn in at least five important proportions, that is, its intrinsic importance, its personal role, its social role, its process role, and its empowerment role; and United Nations Development Project (UNDP) includes educational capability among the utmost important dimensions of human development. In India, where educational access has conventionally been confined to upper castes, the spread of education among socially disadvantaged groups have substantial implications for their economic progress. Therefore, improved education can have vital concerns for the plans and implementation of development

strategies and their impact on the poor. Educational level (from primary to higher level) is crucial indicator for knowing the educational attainment of people. As per 2011 census, the literacy rate is 69.7 per cent which is a 23.80 percentage point rise over the previous rate of 56.3 per cent in 2001. Nevertheless, the gap between male literacy rates 79.2 per cent and female literacy rate 59.3 per cent is very high in Uttar Pradesh.

Methodology and Universe of Study

The study areas for the purpose of household mapping were selected after taking an overview of all areas in Ghaziabad city and in Mathura city, and discussions with different stakeholders. Relevant primary and secondary in-hand information was also gathered about selected settlements before mapping the households. The first step involved in household mapping was based on primary and secondary information gathered from various sources including government departments, literature studies conducted in the city, and information available from other stakeholders in both cities. The second step involved assessment of the socio-economic condition of the settlements, specifically the issue of education among the communities within the settlements. There is a huge gap of basic physical and social infrastructure in the slums and which requires immediate attention at policy and programme level (Table:1). The third step involved assessment of socio-economic condition of settlements, specifically issue of education among the communities within settlements. Characteristics of settlements and community were noted; and the relevant informations were captured.

Cottlomont	Word	Hausshalda	Donulation	DDI	
Settlement	waru	nousenoias	Population	DPL Bonulation	
	NU			Population	
Mohan Nagar	24	360	2875	315	Ambedkar nagar has 6 slum
Ambedkar	12	435	3775	400	pockets with 12300 total
Nagar					population, having 55.28% SC
					population.
Sadar	13	130	1147	93	Antapada has 7 slum pockets with
Baadpura	35	78	620	63	12150 total population, having
Antapada	18	235	1850	212	53.99% SC population.
Rani ki Mandi	6	205	1840	188	Rani ki Mandi has 3 slum pockets
					with 5720 total population, having
					51.57% SC population
Naya Nagla	11	398	3590	362	Naya Nagla, Jhingurpura,
Jhingurpura	11	484	3875	402	Bahadurpura, Khatik Basti has 4
Bahadurpura	11	420	3380	357	slum pockets with 12650 total
					population, having 77.87% SC
					population
					Baadpura has 3 slum pockets with
					2860 total population, having
					50.70% SC population
Manoharpura	3	500	4620	515	Manoharpura – has 3 slum
					pockets, with 13450 total

Table 1: Settlement Details

population, having 48.77% SC population.The major Nala of Mathura, Masani Nala, falls in this zone along with Gopalpura. The population of this zone including the floating population of 13900 comes as 140257.

During the first phase, household mapping survey conducted in four areas/zones of each city. The mapping survey was mainly aimed at identifying the complete listing of households engaged in "Unclean" occupation; as well as the children who belong to school/college going age-group of 4-21 years, along with their present status of education. It is found that majority of the settlement dwellers derive their livelihood as working labor in government or non-government sector), self-employed, domestic helpers, etc.

Household mapping was done in context of the clean and "Unclean" occupation/caste communities and were identified from the socio-economic background which would serve as a basis for making an assessment of exclusion, for final data collection.

Selected Settlements

Considering the existing setting of the cities, the selected settlements in both Ghaziabad City and Mathura City were divided into four areas/zones respectively, on the basis of existence of scheduled caste population predominantly (Table: 2). Settlements were identified in each of the four urban areasin both places, having a mixed population of 250-500 households while ensuring that each settlement comprises of households (irrespective of any specific caste community) presently engaged in "Unclean" occupations as well as those households whose members (grand-parents, parents, siblings, spouse, or children) had remained engaged in "Unclean" works either in the recent past within last five years, or last five to ten years or even before last ten years. An equal proportion of 250 households were selected from all the four areas both in Ghaziabad City and in Mathura City. In total, 1000 households, as total households listed for mapping for the research study.

City	Zone	No of Households	Total
Ghaziabad City	Vijay Nagar	250	1000
	Bus Stand Area	250	
	Kavi Nagar	250	
	Mohan Nagar	250	
Mathura City	Baadh-pura	250	1000
	Khateek Mohalla	45	
	Gopal-pura	116	

Table 2: Settlements (Zone-Wise) and No of Households in Two Cities

Total		2000
	Jhingur-pura	64
	Naya Nagla	79
	Bahadur-pura	107
	Ambedkar Nagar	58
	Rani Mandi	192
	Anta Pada	52
	Manohar-pura	37

Coverage of Households

Table 3 shows, social group classification in terms of major caste categories reflecting that out of a total 2000 surveyed households in two cities, there are a highest of 67 % households belonging to scheduled caste category, than 20.2 % of OBC category, 8.2 % of general caste category, and households 4.6 % of Muslim category. City-wise classification of these major four caste categories reflected the similar trend in both the cities (Ghaziabad and Mathura). It is further observed that out ofa total of 1339 SC households surveyed, a higher percentage of nearly 80 % households are in Ghaziabad City than 54.6 % households in Mathura City belong to SC category. A higher proportion of almost one-third surveyed households were from OBC category in Mathura City, than 11.4 % households in Ghaziabad City; and a similar higher of nearly 7 %) households were from Muslim category in Mathura City, than just 2 % households in Ghaziabad City.

Caste Category	Gha	aziabad City	Mat	hura City	Total		
	No	Per cent	No	Per cent	No	Per cent	
SCs	793	79.3%	546	54.6%	1339	67.0%	
OBCs	115	11.4%	291	29.1%	406	20.2%	
General Castes	72	7.2%	92	9.2%	164	8.2%	
Muslims	20	2.1%	71	7.1%	91	4.6%	
Total	1000	100%	1000	100%	2000	100%	

Table 3: City-wise Major Caste Categories of Households

Status of cities in terms of caste-wise distribution of the surveyed SC, OBC, General and Muslim households reveals that among SCs (793), there were maximum number of Valmikis, followed by Jatav, Kori, Pasi, other SCs (including Dhobi, Gond, Kaitwar; Kanchi; Kandere; Kharwar; Puraniyan; Sahasi; Satnami, and Vanshkar) Khatik; Chamar and Koli; among OBCs including Barai, Bhurji, Chauhan, Chipi, Darji,Dhivar, Goswami, Gujar, Jaat, Jogi, Julaha, Kahar, Katariya, Kurmi, Kushwaha, Mali; Mallaha, Patel,Rajbhar, and Teli, followed by Ahir, Prajapati/Kumhar, Gadariya and Kashyap, Sonar, Lohar/Panchal, Lodha/Lodhi and Saini; among Muslims including Saifis, Shaikh, Maniyar, Abbasi, Kabadi and one other; and among general castes including Kshatriyas, Brahmin, Baniyas, Jaiswal and Tyagi, Bhumihar, Sisodia and Tomar out of total 1000 surveyed households in Ghaziabad City. While in Mathura City out of 1000 surveyed households, among SCs (546 households), there were maximum number of Valmikis, followed by Jatava, other SCs (including Arya, Barwar, Dhangar, Dhobi,Jadon, and Maahor, Kori, Raigad, Koli, Khatik, and Chamar; among OBCs, maximum number of Gadariya, followed by other OBCs

(including Baghel, Banjara, Barai, Chauhan, Jaat, Jogi,Kewat, Kushwaha, Maurya, Meena, Nai, Nat,Ruhela,and Sidhi), Prajapati/Kumhar, Ahir, Saini, Kashyap, Sonar, and Lodha/Lodhi; among Muslims including Abbasi, Dhobi, Farukhi, Kuraisi, Lohar, Maniyar, Mansoori, Pathan, Rangrez, Saifi, Shaikh, and others; and among general castes, included Baniya, Brahmin, Kayastha, Kshatriya, Punjabi and Valai.

Household Engagement and City Location

Household engagement in clean occupation and in "Unclean" occupation (Table 4) reveals that out of 2000 households surveyed in Uttar Pradesh, a higher of 55 % (1098 households) were reported to beengaged in "Unclean" occupation, in an aggregate manner, either presently or in the recent or remote past – as members of previous generation, present generation, or future generation within thesurveyed households. This aggregate situation reported the similar trend in the Ghaziabad City (546 households) and in Mathura City (552 households).

City-wise data in terms of present engagement in "Unclean" occupation, showed that a higher percentage of 52.4 % households in Ghaziabad City (out of 1000 households) than 31.1 % households in Mathura City (out of 1000 households). While the family history of engagement in "Unclean" occupation shows that a higher per cent of 24.1 % (241 households) surveyed in Mathura City stated about their engagement in the past also, but in Ghaziabad City only 2.2 % (22 households) stated about their involvement in "Unclean" works only in the past, by their household members. Thus, occupational mobility is higher in Mathura city. It can be noted that less than half of the total surveyed 2000 households were those "never involved into "Unclean" occupation". This trendwas noted the same for Ghaziabad City (45.4 %) and for Mathura City (44.8 %).

G	haziabad (City	Mathura	City	To	tal
	No	%	No	%	No	%
Currently Engaged in "Unclean" occupation	524	52.4	311	31.1	835	41.8
Currently Not Engaged in "Unclean" occupation	22	2.2	241	24.1	263	13.2
Never Engaged in "Unclean" occupa	ati 454	45.4	448	44.8	902	45.1
Total	1000	100.0	1000	100.0	2000	100.0

Table 4: City-wise Household Engagement in "Unclean" Occupation

Caste and Association with "Unclean" Occupation

Caste-wise distribution of household engagement in "unclean" occupation (Table 5), analysis says that out of 2000 surveyed households, 835 (41.8 %) were found currently engaged in "Unclean" occupation – of which maximum (817) households were from SC category (including Valmiki, Pasi, Khatik, Jatav, Raigad and others), followed by OBC category (14 households) (including Prajapati/Kumhar, Kashyap, Gadariya, Ahir, Dhobi, and others), and four Muslim households. A total of 263 (13.2 %) surveyed households were those who were presently not

engaged in any kind of "Unclean" occupation, and had given up such works – of which maximum (146 households) were from SC category (including Valmiki, Pasi, Jatav, Raigad, and others), followed by OBC category (116) (including Prajapati/Kumhar, Gadariya, Ahir and others), and one Muslim household.

A total of 902 (45.1 %) surveyed households , the data shows that they were never engaged into "Unclean" occupations; of which, settlement-wise, these were 172 households from Mohan Nagar that is, north-zone, 132 households from Vajay Nagar that is, south-zone, 107 households from Kavi Nagar that is, east-zone and 43 households from central-zone, that is Bus-Stand Area in Ghaziabad City; while 140 households were from Baadhpura and 15 households from Khateek Mohalla (that is, south-east zone), 15 households from Manoharpura, 52 households from Gopalpura, 10 households from Antapada (that is, central-zone), 91 households were from Rani Mandi, 22 households from Ambedkar Nagar (that is, north-zone), and 32 households from Bahadurpura, 31 households from Naya Nagla, 40 households from Jhingurpura (that is, south-zone) in Mathura City. Of those 902 households, highest of 376 households belonged to SC category (including – Valmiki, Pasi, Khatik, Koli, Kori, Jatav and others).

Thus, on an overall basis, out of 2000 surveyed households, as high as 41.8% (835 households) are still engaged into "Unclean" occupation, involving mainly SCs (97.8 %, 817 households). Similar trendwas observed in Ghaziabad City (with proportion of 99%, 519 SC households) and in Mathura City (with proportion of 95.8%, 298 SC households) – presently involved into "Unclean" occupation. And only 13.2 % (263 households) have given up "Unclean" occupation, involving mainly SCs (146 households, 55.5 %) and OBCs (116 households, 44.1%), with all households from SC category in Ghaziabad City and with 48% to 52% from OBC and SC category in Mathura City and just one Muslim household from Mathura City itself.

Household Caste Ghaziabad City	Mathura City	Total					
Engagement	Categories	No	Percent	No	Percent	No	Percent
Currently Engaged	SCs	519	99.0%	298	95.8%	817	97.8%
	OBCs	2	.4%	12	3.9%	14	1.7%
	Muslims	3	.6%	1	.3%	4	.5%
	Total	524	100.0%	311	100.0%	835	100.0%
Currently Not Engaged	SCs	22	100.0%	124	51.5%	146	55.5%
	OBCs			116	48.1%	116	44.1%
	Muslims			1	.4%	1	.4%
	Total	22	100.0%	241	100.0%	263	100.0%

Table 5: Caste-Wise Household Engagement in "Unclean" Occupation inGhaziabad & Mathura





Among 22 households in Ghaziabad City, 21 households had withdrawn from engaging into "Unclean" occupation during last 5-10 years ago (maximum from Vijay Nagar, minimum from Mohan Nagar), one household from Vijay Nagar before last 10 years; and among 241 households in MathuraCity, 125 households had withdrawn ten years ago – maximum from Bahadurpura and Gopalpura, minimum from Rani Mandi; 85 households had withdrawn during last 5-10 years – maximum from Ambedkar Nagar and Baadhpura, minimum from Antapada and Jhingurpura; 31 households had withdrawn during last 5 years – maximum from Baadhpura and one household from Ambedkar Nagar (Figure: 1; Figure: 2).



Figure: 2: Households Presently Not Engaged into "Unclean" Occupations in Two Cities



Overall the educational status of children (4-21 years age group) of total 4637 children from 2000 surveyed households was analysed from three main viewpoints, that is, the status of school going children who still continue education; status of dropout children who have discontinued education, and children who never attended any educational institution. Figure: 4 shows that, out of 2000 surveyed households, a high 76.6% (3551 children) were found 'Continuing education' category, followed by 16.3% (756 children) were the 'drop-outs', 6.8% (313 households) had 'never attended' any schooling or education, and just 0.4% (17 children) were reported to have

'completed' their education. A dropout has been considered as any student who is enrolled and leaves school for any reason before graduation or completion of a program of studies without transferring to another elementary, secondary, or any level of education. A completed education has been considered the years of completed education referring to the number of academic years a child completes in a formaleducational program provided by elementary and secondary schools, universities, colleges or other formal post-secondary institutions.



Figure 4: Educational Status of Children

These 4637 selected children, were classified into four categories, that is, those who were undergoing education, those who were enrolled but were the drop-outs from their education or had discontinued from their educational institution, those who had completed their schooling or college level of education, and those who never enrolled, attempted or attended schools for their education. Age-wise, only those children below 4 years, were recorded who were enrolled and entered into schooling; while only those children above 21 years of age were recorded whose educational status was into 'Continuing education' category.

Figure 5 shows that overall, out of 4637 children, a higher of 51 % (2380) children from Mathura City, than 49% (2257) children from Ghaziabad City recorded for the purpose of study. City-wise analysis of the educational status of children shows the same order, that in Mathura City, out of 2380 children, proportionately a higher of 79.9% (1902 children) had Continuing education status, followed by 12.6% (300 children) with drop-out status, 7.1% (168 children) with never attended status and just 0.4% (10 children) had completed educational status. While, in Ghaziabad City, out of 2257 children, proportionately, a highest of 73.1% (1649 children) had Continuing education status, followed by 20.2% (456 children) with drop-out status, 6.4% (145 children) with neverattended status and just 0.3% (7 children) had completed their education. Thus, educational status-wise, the data reveals that in terms of 'Continuing education' (3551 children), Mathura City (53.6%, 1902 children) has performed better than Ghaziabad City (46.4%, 1649 children), in terms of 'drop-out' status (756 children), Ghaziabad City (60.3%, 456 children) had more reported cases than in Mathura City (39.7%, 300 children). Interestingly, in terms of 'never attended' (313 children) status, also, Mathura City (53.7%, 168 children) was at a higher level than in Ghaziabad City (46.3%, 145 children).



Figure 5: City-wise Educational Status of Surveyed Children

Household Level of Occupational Engagement of Surveyed Children

Table 6 analyses educational status of 4637 surveyed children on the basis of occupational engagement, it was noted that households of 43.8% (2031 children) are presently engaged in "Unclean" occupation, interestingly the households of an equal of 43.6% (2022 children) were those never engaged in "Unclean" occupation; while households of 12% (584 children) were those whohave given-up "Unclean" occupation, and they are presently not engaged in any kind of "Unclean" work, as a means of their livelihood.

Among the 17 children who had 'completed' their education, proportionately, maximum number of children (52.9%) were from those households who were never engaged in "Unclean" occupation, followed by 29.4% whose households had given up the "Unclean" occupation and a least 17.6% were from those households still engaged in "Unclean" occupation.

Among the 313 children who had 'never attended' any educational institution, proportionally, maximum number of children (63.3%) were from those households still engaged in "Unclean" occupation, 30 % belonged to those households who were never engaged into "Unclean" occupation, and interestingly the figures were noted to be minimum at 6.7% belonging to those households who had given up the "Unclean" occupation as a means of their livelihood.

Among the 756 children who reported to have 'dropped-out' as their educational status, proportionally, maximum number of children (67.2%) belong to those households who are presently engaged into "Unclean" occupation, than 28.3% who belong to those households who were never engaged in "Unclean" work, and 4.5% households who have given up the "Unclean" work as their livelihood option.

Among the 3551 children with 'Continuing education' proportionally, maximum number of children (48%) belong to those households who were never engaged into "Unclean" occupation, than

37.2% who are presently engaged into "Unclean" occupation, and 14.8% whose households have given up the "Unclean" work as their livelihood option.

Specifically, among 2031 children belonging to those households presently engaged in "Unclean" occupation, reflected a maximum of 65.1% children having 'Continuing education' status, followed by 25% children having 'drop-out' status, 9.7% children as 'never-attended' status, and just negligible, three children who were found 'completed' their education.

		Education Status								
	Co	mpleted	Cor	itinuing	D	ropout	1	Vever	٦	Total
			edu	ucation			at	tended		
							S	School		
	No	%	No	%	No	%	No	%	No	%
Presently	3	17.6%	1322	37.2%	508	67.2%	198	63.3%	2031	43.8%
Associated with										
"Unclean" Works										
Presently Not	5	29.4%	524	14.8%	34	4.5%	21	6.7%	584	12.6%
Associated with										
"Unclean" Works										
Never Associated	9	52.9%	1705	48.0%	214	28.3%	94	30.0%	2022	43.6%
with "Unclean"										
Works										
Total	17	100.0%	3551	100.0%	756	100.0%	313	100.0%	4637	100.0%

Table 6: Educational Status and Household Occupational Engagement of Surveyed Children

Class Level of Educational Status of Children

Table 7 reveals an overall analysis of educational status of children served on the basis of their educational levels, that is, upto mid-primary level (including pre-primary, primary, middle-primary), upto under-graduation level (including secondary, that is, ninth and tenth standard; higher secondary, that is, eleventh and twelfth standard; under-graduation), upto post-graduation level (including graduation and post-graduation). Of the total 4637 children, 4324 children recorded were those who had completed their education, those who are still in their Continuing education stage and those who had enrolled in an educational institution but were the drop-outs. Out of 4324 total enrolled children, ahighest of 71.2 % (3077 children) were upto the middle-primary level, followed by 26.6% (1149 children) were upto under-graduation level, and just 2.3% (98 children) were upto post-graduation level.

Educational Level of children	Completed		Continuing education		Dropout		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Pre-Primary			475	13.4%	4	0.5%	479	11.1%
Primary			1395	39.3%	365	48.3%	1760	40.7%
Middle Primary			620	17.5%	218	28.8%	838	19.4%
Secondary			463	13.0%	125	16.5%	588	13.6%
HigherSecondary			360	10.1%	39	5.2%	399	9.2%
Under-graduation			159	4.5%	3	0.4%	162	3.7%
Graduation	15	88.2%	67	1.9%	1	0.1%	83	1.9%
Post-graduation	2	11.8%	12	0.3%	1	0.1%	15	0.3%
Total	17	100.0%	3551	100.0%	756	100.0%	4324	100.0%

Table 7: Class-wise Educational Status of Total Children

Further, it was noted that, of the 3077 children enrolled upto middle-primary level, a higher of 80.9% (2490 children) were those still Continuing education and 19.1% (587 children) had dropped-out from their education. With regard to education upto under-graduation level of education of 1149 children, a higher of 85.5% (982 children) were those, still Continuing education and 14.5 % (167 children) had dropped-out from their education. And, with regard to education upto post-graduation level of 98 children, a higher of 80.7% (79 children) were of the Continuing education status, just 2% (2 children)had a status of drop-out, and 17.3% (17 children) were those who had completed their education.

In terms of 'Continuing education status', the data shows that, it was higher at the level 'upto middle- primary' (70%), followed by 'upto under-graduation' level (28%) and just 2% at the level 'upto post- graduation', in terms of 'drop-out' status the data shows that this too was higher at the level 'uptomiddle-primary' (78%), and then 'upto under-graduation' level (22%), while the drop-out status was negligible, at the level when reaching 'upto post-graduation' stage.

Caste Category and Educational Status of Children

Further analysis of caste-category-wise educational status of the total 4637 sample children out of 2000 surveyed households in Uttar Pradesh, was based on major social groups or caste categories, that are, scheduled castes (SCs) (3123 children – of castes – Valmiki, Jatav, Kori, other SCs, Pasi, Raigad, Koli, Khatik), other backward castes (OBCs) (936 children – of castes – other OBCs, Gadariya, Ahir, Prajapati/Kumhar, Kashyap, Saini, Sonar, Lodha/Lodhi, Lohar/Panchal), general castes (329 children) and Muslims (249 children). The educational status of 3123 SC-children showsa major proportion of 72.7% (2270 children, of castes – Valmiki, Jatav, Kori, other SCs, Pasi, Koli, Raigad, Khatik) in 'Continuing education status' followed by 19.4% (605 children, of castes – Valmiki, Jatav, Kori, Pasi, other SCs, Raigad, Khatik, Koli) in 'drop-out' status, 7.6% (236 children, of castes – Valmiki, Jatav, Raigad, other SCs, Khatik,Kori, Koli) in 'never-attended' status and just 0.4% (12 children, of castes – Valmiki, Jatav, Kori, other SCs) of 'completed' status of education (Table 9).

Education Status	ę	SCs	C)BCs	G	eneral astes	M	uslims	Т	otal
	No	%	No	%	No	%	No	%	No	%
Completed	12	0.4%	4	0.4%	0	0.0%	1	0.4%	17	0.4%
Continuing	2270	72.7%	821	87.7%	291	88.4%	169	67.9%	3551	76.6%
education										
Dropout	605	19.4%	79	8.4%	35	10.6%	37	14.9%	756	16.3%
Never attended	236	7.6%	32	3.4%	3	0.9%	42	16.9%	313	6.8%
School										
Total	3123	100.0%	936	100.0%	329	100.0%	249	100.0%	4637	100.0%

Table 9: Caste-Category-wise Educational Status of Surveyed Children in Uttar Pradesh

Thus, the proportion of children with 'Continuing education' status was highest among the general caste category and OBC-children, than the SC category and Muslim category children. Also, in addition to the situation, it was noted that the proportion of children who 'never-attended' educational institution was lowest among the general caste category, and highest among the Muslim children, followed by SC-children and OBC-children. With regard to the 'drop-out' status, the proportion of children in this category was noted to be highest among SC-children and Muslim-children, than the children belonging to general castes and OBC-category.While, an equal proportion of children who 'completed' their education was noted among SCs, OBCs, and Muslim categories.

"Unclean" Occupation and Educational Status of Children

Table 10 shows city-wise distribution of educational status of 2031 children's household presently engaged in "Unclean" occupation, shows Ghaziabad City, 60% having its higher involvement than Mathura City, 40% children. However, an analysis of the different states of educational status among the two selected cities, reflected somewhat nearly same range of proportions at 'Continuing education' status (Ghaziabad City, 63.6%; Mathura City, 67.4%), followed by 'dropout' status (Ghaziabad City, 27.4%; Mathura City, 21.4%), 'never-attended' status (Ghaziabad City, 8.9%; Mathura City, 11.1%), and 'completed' status (Ghaziabad City, 0.2%; Mathura City, 0.1%).

Educational Status	Ghazi	Ghaziabad City		hura City	Total		
	No.	Per cent	No	Per cent	No	Per cent	
Completed	2	0.2%	1	0.1%	3	0.1%	
Continuing education	780	63.6%	542	67.4%	1322	65.1%	
Dropout	336	27.4%	172	21.4%	508	25.0%	
Never attended School	109	8.9%	89	11.1%	198	9.7%	
Total	1227	100.0%	804	100.0%	2031	100.0%	

Table 10: Educational Status of Children from Households Engaged in "Unclean"Occupation

Social, Economic, Cultural Causes that Promote Education of Children

The effects of socio-economic, cultural and infrastructural aspects on educational enrolment of children showed that most of the disparity in educational participation was due to factors at the household level. Of the household-level factors, socio-economic resources are the most important. If the parents have education, or if they are not very poor, the likelihood of children being in educational institution is considerably increased. Household economic status is mainly significant in urban settlements where, probability of children being in school is higher. Parental education is important in these urban settlement areas, having a literate household head also increases the probability of children being in school. Mothers with some knowledge are thus better able, or motivated, to get their daughters into school. Of the other socio-economic factors, motivation of the mother showed a positiveeffect. In the selected cities, the decision of parents to send their children to school is influenced by supply-side factors to some extent, that included school characteristics, if there are more or better primary schools, educational participation of girls is increased, and if the distance to the nearest schoolis longer both girls and boys are less in school.

-Mother's motivation towards children's education

-Studying through self-employment

-Realising the importance of education

-No gender difference at home

-Good peer interaction and motivation within school and college environment

-Local residential environment, housing conditions and clean work association in the settlement conducive to education

Social, Economic, Cultural causes that Hinder Education of Children

The several social, economic, cultural and physical factors that combine to hold back education amongmarginalized communities in the selected settlements are taken together, in the forms of qualitative case studies, focused group discussions, personal interviews at the levels of parents and students. There are even the added impediments of cultural beliefs that prevent many from enrolling or completing school. Sometimes there are social or cultural factors that hold back education among children. Discrimination is one of these. There are several factors hindering or leading to failure of education of children. They range from those, which are due to irresponsiveness of parents, teachers, social environment of education in school or college, poor quality of education, low motivation, lack of commitment and weak supervision rendered by the parents at home, and discriminatory practices among others.

-Experiences of Discrimination, Caste Abuse, Un-touchability

-Parents still engaged in Unclean Works

- -Engaged in unclean work in the past
- -Poverty and present engagement in unclean works
- -Early marriage and became parents at an early age
- -Religious norms influencing education
- -Lack of motivation
- -Addiction to liquor consumption and gambling

-Mothers' concern that both caste factor and poverty are unfavorable towards children's education

These are factors that influence education of children and examines exhaustively from domains of disadvantaged backgrounds to estimate the extent of socio-economic, family, individual and contextual causes on educational performance. Briefly, it supports the notion that the social, cultural and the economic components of the socio-economic status equation has divergent influences on children's educational outcome.

Impact of Discrimination and Exclusion of Children

The effects and consequences of discrimination and exclusion of children among marginalized communities in the selected settlements are taken together, in the forms of qualitative case studies, focused group discussions, personal interviews at the levels of parents and students. Impacts include loneliness, possible exclusion, demoralization, and marginalization, situations where self-esteem and self-confidence have the potential to be harmed. Discrimination against any child regardless of their needs can make them feel isolated and different to other children. The potential areas for the impact of discrimination included physical, emotional, social and intellectual. The manifested signs included attempting suicide, physical abuse, loss of self worth, lack of friends, social exclusion, disinterested tolearn, etc.

-The Caste Struggle and Education Challenge

-Victim of Un-touchability

-Lack of interest towards education, cigarette smoking and liquor consumption result in dropouts -Problem of low attendance and absenteeism

- -Issue of being irregular and not punctual
- -Continued engagement in unclean works

-Punishment after caste conflict in classroom ended up in manual scavenging

-Discrimination by teacher in school, violence due to caste conflict

The interaction analyses with respect to the cultural factors revealed mixed results, suggesting that caste and gender still play an important role in India and that for getting all children into school, policies aimed at strengthening the position of women and the lower castes remain very significant. It is important to note the efforts being made through various policies and programmes in order to reduce social gaps and also gap in education. More importantly, only years of schooling is not same of learning. The more worrying is that even the progress made so far on standardized tests such as OECD, if nothing changes, like many developing countries, it will also be a long road for India as well (WDR,2018)

Major Suggestions to Evolve a Comprehensive Educational Policy

The present analytical study on discrimination and exclusion in education in the realm of household background of presently engaged in unclean occupation or given up unclean occupation, has acquainted with the actual state of affairs in Uttar Pradesh. This study has dealt with undertakings in schools, in consideration with indicator-wise social contextuality and education status in terms of continuing education, dropping out from educational institution, and never attending any educational institution. The study has highlighted prevailing or probable discriminatory practices in the educational institution. The most evident occurrences of discrimination have come to notice in areas as teacher and student relations, and among the students peer group, wherein caste based discrimination and gender differences continues.

Future policy for educational development in Uttar Pradesh should pay consideration to the resulting concerns, as mentioned below:

-Attainment of aim of universalization of primary education requires creation of additional proficiencies by introducing new secondary schools and institutions of higher learning vital to manage the increasing outflows from the lower levels.

- Together with growth in physical infrastructure and other facilities, quality of education needs to be strengthened. Quality has to be the guarantee of education in future and Uttar Pradesh that remains regressive in quality education will be too weak to become equal with the forward states in virtually every single respect. The push consequently will have to be on quality improvement along with quantitative development.

- Among the selected sample it was noted that there are households where number of children are more than two. The big family size becomes an impediment for the children to enjoy private space for their work as well as for studies within the home. Further due to high dependency ratio, it is very not easy for the care takers or parents to fulfill the necessary demands of children towards their studies. Further increase in population of poor section directly imbalances the demand and supply cycle of labour and market. The easy availability of large number of labourer

leads to low dignity of labour. In India where labourers are mainly from dalit community further draws attention to the position of this community into lower level and results in losing of their bargaining power. Therefore, to break this vicious circle of poverty and dependency the state and central government need to adopt a strict policy of one or two child policy as adopted in some states of India. Strict government policy of family planning could be the most valuable way to deal with this problem.

- Reducing the gender gap in education and justifying the educational disadvantages of the scheduled castes and other backward classes will need to be taken care of more effectively with a view to promote their educational development in particular and the integrated social developmentin general.

- Exceptional consideration has to be paid to children of the marginalized sections like manual scavengers, dhobis, sweepers, migrants, and other unclean workers, etc. and valmiki children.

- Consideration will have to be fixated on promotion of primary education in the lagging districts and slum pockets of cities.

- Even with the universalisation of primary education Uttar Pradesh will remain oppressed with a large mass of illiterate parents for a long time to come. Special programmes are thus desired for promoting literacy and functional skills for such parents, and other illiterate young community men and women. Audio and visual techniques can be efficiently developed for this purpose.

- Financing pattern and grants in aid criteria for improvement in quality of school education and university education of all types, mainly in government aided educational institutions need to be restructured so that they compete in the changed scenario of inter-state and international competition with success.

- Technical education needs to be promoted to meet the emerging challenges and to provide employment opportunities to the youth.

- Funding of education has to be considerably upgraded to improve the quality of infrastructure and education. Neglect of higher education will be damaging to the benefits of the state and the country in the long run.

- System of education in Uttar Pradesh is progressively moving from state controlled and state financed to privately managed and privately funded system. Yet, the state still has a key part to play. Rise in fee structure in future is inevitable so is likely to have "user charging education system". So for making the government subsidized system of education to fee charging one, a political consent will be needed. Though, together with making the system more fee charging, provision will have to be made for free-ships to poor students from all social categories so as not to deprive them of education along-with facility of educational loans.

- Involvement of local communities and parents' associations will be accommodating in keeping absenteeism among teachers and increase the quality of education being delivered in the schools.

- There needs to be due recognition of space for dalit culture, ideology and icons in the schools. In such scenarios a student from scheduled caste community finds extremely difficult to develop empathy with the school system. Hence, the school syllabus normally should take notice of dalit literature and issues related to caste, exclusion and discriminations in its curriculum.

- A majority of children study till 14 years of age in Uttar Pradesh. As the age increases, there is a drop in the number of children who continue with their education in both selected cities. The data also reveals that very few children continue to study till secondary level of education. Dropout figures are lower at 10-14 years. A majority of children study till 14 years of age. As the age increases the dropouts keep increasing. Very few continue to study as age advances. A majority ofchildren never attended any educational institution as the age advanced and seemed to lose interest in their studies. There is no apparent gender difference in 'never attended' amongst households currently engaged into unclean occupation particularly upto 10-14 years age group and 18-21 years age group in Ghaziabad city; and upto 10-14 years age group in Mathura city.

Large numbers of children go to government schools, followed by high percentage of children going to private unaided schools. The percentage of children who continue to go to local body schools isdismal. Private unaided schools are gaining prominence in Uttar Pradesh. Female children are reported to go mainly to government schools; while male children usually go to private schools. Major proportion of dropout children were reported from households involved into unclean occupation. Gender difference was observed in dropouts amongst currently engaged in unclean occupation, wheremales was higher than females irrespective of school type. Private unaided schools are gaining prominence to some extent in Ghaziabad more than Mathura. Large numbers of children go togovernment schools. Dropout cases in local body schools are also noted. Further, this has raised a range of issues relating to female well-being being erased from the policy map. Girls disappear from formal education policy agenda past the age of 14, at a critical age when aspirations can be channeledinto opportunities.

The study reveals that there is no apparent gender discrimination in continuing education amongst currently engaged in unclean occupation. Although higher of male children do go to English medium institution, yet Hindi is the most preferred medium compared to English for both females and males. Higher percentage of 46.1 % female children goes to Hindi medium educational institutions in Mathura city. Hindi was the most preferred medium among the dropout children in Uttar Pradesh. Male dropout children were observed to be going to Hindi medium educational institutions.

The urban poverty is the most prevailing factor that forces many from traditionally clean occupation to take up unclean work, as evident from case of Ahir, Gadariya in Mathura, and Kashyap in Ghaziabad. The status of continuing education for boys is higher amongst Valmikis in Ghaziabad; and is lower for boys in Mathura. The urban poverty is the overriding factor that forces many from traditionally clean occupation to take up unclean work, as evident from case of

Kumhar and Ahir in Mathura. The dropoutfor boys is higher amongst Valmikis, Khatik, and Raigad. The situation of never attended is higher amongst Scheduled Castes Valmikis, and nil amongst Kashyap, Gadariya, Ahir caste communities.

The status of continuing education is high when household heads are educated or literate. Parents' illiteracy was not too much a factor leading to dropout. The situation of never attending any educational institution drops when the households' heads have higher education.

Thus, study indicates that the education status of children associated with unclean occupation has improved to some extent because of Right of Children to Free and Compulsory Education Act, which provides for free and compulsory education to all children aged 6 to 14 which is anchored in principles of equity and non-discrimination. However the education completion has not gone much at higher levels due to the fact that dropout is high at secondary and primary level. The reason of poor educational achievements is household related social and economic; poverty, low literacy of parents, intra-household and community settings and living conditions. Nevertheless discrimination and exclusion happens to be the main issue for their educational backwardness in terms of access to school, school type, infrastructure, provisions and facilities in school, inclusive behavior and attitude of authorities in the institution, teachers and peer groups. These result in students' participation, withholding, attainment, and completion of education. The disparity along caste lines is evident in the educational process. Poverty is a factor for dropout situation in Uttar Pradesh. The dropout declines as the income of the household increases in both cities. Highest degree of never attended any educational institution is among children from those households below poverty line. The situation of 'never attended' drops as the income of the household increases.

In Mathura city, which is much smaller than Ghaziabad city lacks growth dynamism. The the wellbeing index even among the low income households seems to have a positive association with city size andit tends to vary with the nature of the city, that tends to suggest that even when consumption poverty ishigh, many other facilities which are available in the cities contribute to the well-being of the population. However, it is noted that even in the so-called dynamic cities the percentage of slum households located in the bottom size classes is not negligible either, suggesting that growth alone cannot eradicate poverty. Availability of more demand-induced employment opportunities in the big city, in terms of several socio-economic development indicators verified that it tends to improve with a rise in city size. Economic globalization has not reduced the intra-urban growth differentials. The agglomeration economies continue to exist because the new forces in the present context of economic globalization have emerged to substitute the forces which explained their prevalenceway back have been on the decline. This is, however, not to deny the considerable overlaps that may exist between informal sector employment, poverty, and slums in the big city. Since the big city is more productive in terms of a wide range of socio-economic indicators the low income households in the big city is likely to be better-off in big city relative to their counterparts in small urban settlements.

Micro evidence suggests that big city tends to improve the wellbeing of the population even among thelow income households. The percentage of slum households at the bottom size classes is

much larger in the stagnant and small urban settlements compared to the large and relatively dynamic ones. However, several of the sample households even in big city are located in the bottom size classes. For them to experience an upward mobility the urban employment programmes are pertinent. Most of the urban specific programmes in India largely emphasize the importance of basic amenities to the urban poor and infrastructure need of the cities. However, improvement in educational support can have longlasting effect on poverty.

Conclusions

The empirical drawn data analysis shows that the urban poverty is the overriding factor that forces many youth from traditionally marginalization section of the communities to dropout and shift from clean occupation to unclean work. The findings describe that the status of continuing education is high when household heads are educated or literate. However, it also indicates that parents' illiteracy was not too much a factor leading to dropout, but to some extent, education status of children associated with unclean occupation has improved because of affirmative actions (AAs). especially Right To Education Act (RTE, 2009), which is anchored in principles of equity and nondiscrimination. Further, the education completion has not gone much at higher levels due to the fact that dropout is high atboth primary and secondary levels. Most children get education till primary level. Gender difference was observed in dropouts amongst households currently engaged in unclean occupation, where the male children were higher in proportion than female children. However, there is a neglect of female post-primary education in the stated region of Uttar Pradesh. This is something in contrast to both human capital and inclusive theory, where 'gender' perspective is more important, and female education have been crucial discourses of education policy, ensuing girls' education and women empowerment as a tool of equality cum inclusive development and sustainable progress. Further, discrimination and exclusion on the basis of caste and gender happens to be the main issue for their educational backwardness in terms of access to school, school type, infrastructure, provisions and facilities in school, inclusive behaviour and attitude of authorities in the institution, teachers and peer groups. Further, the deeper social analysis shows that disparity along caste lines is still evident in the educational process across regions. It also shows the continuity in withdrawal of education among Scheduled Castes and the consequential social inequities attributed to historical and cumulative polity-socio economic deprivation suffered by them for centuries.

This study has sufficiently found that one of the main causes of magnitude of never enrolled and presently out of school children, and high rate of school dropout is chronic poverty which forces children at an early stage of their developmental lives to look for livelihood preference to augment household income in Uttar Pradesh. While poverty remains leading factor for educational withdrawal, the quality of education, is also one of the prominent causes. It is beyond doubt that there has been a significant growth in the number of schools in the country since independence. It's similar to recent all India education survey also highlighted SC habitations have fewer primary schools than those of the higher castes. Therefore, the schools need to reach out to scheduled caste communities and reinforce school-community relations.

The percentage of males and females generally decreases with the increase in the level of education. In the case of male it increases at the level of primary and middle level education while in case of females it only increases at primary level. In all remaining levels of education it consistently decreases. Gender gap also widens with the increase in level of education. Highest gender gap exists at the level of middle and secondary level of education.

This clearly shows that reason of poor educational achievements is household related social and economic; poverty, low literacy of parents, intra-household and community settings and living conditions. Nevertheless discrimination and exclusion happens to be the main issue for their educational backwardness in terms of access to school, school type, infrastructure, provisions and facilities in school, inclusive behavior and attitude of authorities in the institution, teachers and peer groups. This results in students' participation, withholding, attainment, and completion of education. The outcome shows that disparity along caste lines is evident in the educational process. It is important for concerned districts and state officials to note the effectiveness of the efforts being made through various policies and programs in order to reduce social gaps by enhancing human capital more inclusively. This necessitates drawing an urgent attention and intervention for the policy makersto ensure the social justice and empowerment via educational attainment of the children, especially girls from poor, vulnerable and marginalized communities at large.

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Differential Impact of School Closure on Adolescent Girls during Covid 19 Pandemic: A Study of Slum Dwellers in Delhi

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Abstract

Covid-19 impacted all fragments of society across the world but its impact seems to discriminate between poor and rich, old and young, male and female. These intersectional vulnerabilities paint a complex web of inter-connections that impact various segments based on determinants like age, gender, income status and others. The genesis of the paper lies in the wake of limited research on the social impact of Covid-19 and its consequences on young individuals, especially adolescent girls. This period is crucial for young girls as they undergo numerous transitions related to physical, mental and gendered expectations and decisions. The paper seeks to understand the factors these adolescent girls are exposed to due to the closure of schools from the lens of a consortium of NGOs working towards the empowerment of girls. The exploratory research was conducted using a mixed approach where response was collected from 100 adolescent girls to understand the problems faced by them during pandemic and in-depth interviews of 24 adolescent girls were carried to understand the exposure, sensitivity and adaptive capacity for vulnerability mapping and henceforth suggesting the measures required to mitigate the impact of school closure on adolescent girls during Covid 19 pandemic. The paper addresses the prime concern of Goal 5 of SDG which deals with achieving gender equality and empowering girls and women at a time when these girls are pulled back to domestic obligations due to school closure which is impacting their holistic development and if not addressed instantly might leave its effect for over a generation.

Keywords: School Closure; Differential Impact; Vulnerability mapping; Adolescent Girls; Covid 19; Pandemic; NGO; Government; Policy

Introduction

Adolescent girls in India accounts to a massive neglected population comprising 113 million being systematically denied the advantages of autonomy, economic opportunity and mobility in comparison to their counterparts. Research indicates that adolescent girls are vulnerable in parts of India as 50% of all adolescent girls are married before the age of 18, 95% drop out of school and 50% are exposed to domestic violence (Dasra Report, 2021). 1 in every 3 married girls in the age group 15-19 years experienced violence at hands of their husbands. 1 in every 5 girls of 15-19 years experienced forced sex before marriage and 2 in every 5 girls who were commercially sexually exploited were minors (IIPS, 2006-07; NFHS-3, 2005-06; India Country Report, 2008).

School closure in India impacted 320 million children enrolled from pre-primary to tertiary levels of education. Out of these, about 158 million are female students (UNESCO, 2020). Children studying in government schools were disproportionately affected with more than 80% students not having access to educational resources (Oxfam India Status Report, 2020). It adversely impacted the children coming from the marginalized section of society (poor, unemployed, migrant workers, malnutrition, living in slums and coming from families who lost their source of livelihood and income) and forced many children to discontinue their study even post restoration of normality¹¹. Moreover, it led to unprecedented disruption to education, forced to discontinue education when the primary members lost their jobs, unconsented early marriage, forced pregnancy and sexual exploitation leave many adolescent girls at the risk of discontinuing school post reopening of schools. These girls especially from the marginalized section in domestic chores of the household or provide helping hand in earning.

Government policies have systematically considered adolescent girls, mostly as a subset of women or children group, thus widening a gap for effective policies that address the needs of adolescent girls.

School System Functioning in India

In India, the school system has four levels: lower primary (age 6 to 10 years), upper primary (age 11 to 12 years), high school (13 to 15 years) and higher secondary (17 to 18 years). Students are required to learn a common curriculum according to the board and students have to learn two languages (namely Hindi and English). Central Board of Secondary Education (CBSE) is the most popular board and follows textbook written and published by National Council of Educational Research and Training (NCERT) and many private schools use different text books and follow different teaching schedules. Second most popular board is the Indian Certificate of Secondary Education (ICSE). Both these boards conduct their own examinations at the end of 10 years of schooling and again at the end of 12 years of schooling. Each state in India has its own department of education and runs its own school system, text books and evaluation system and its curriculum and evaluation comes under the preview of State Council of Education Research and Training (SCERT) (Kumar, 2011). There are different category of schools like public/ government schools, private schools, international schools, national open schools and special-needs school.

Indian education system has made significant progress ensuring educational opportunities to all segments of society under the aegis of Right to Education Act, 2009, which entails free and compulsory schooling for children from ages 6 to 14 years. 13.46 million children were out of school in 2006 which reduced to 6.1 million in 2014 (SRI-IMRB Surveys, 2009 and 2014). There has been an improvement but the question arises will this improvement continue? As the situation

¹¹ https://thewire.in/rights/COVID-19-crisis-will-push-millions-of-vulnerable-children-into-child-labour

of pandemic is portraying different figure with economic distress, especially with individuals from marginalized section of society is projected to discontinue sending their children to school.

Adolescent Girls in India: A Potential for Future of India

India is ambitiously nearing to reach the aim of ensuring inclusive and equitable guality education for all and Gender Equality by 2030 under Sustainable Development Goal (SDG) 4 and 5. Progressing in terms of universalizing primary education as visible in the enrolment and completion rate of girls there is a significant drop-out rate of adolescent girls at secondary education level reaching 19.8% as compared to drop-out rate in primary education being 6.3%. (Sonawane, 2020). The Constitution of India conveys a powerful mandate for equality of women in its Preamble, Fundamental Rights and also Directive Principles of State Policy. India is also a signatory to a number of UN Conventions, like Convention on Elimination of all Forms of Discrimination against Women (CEDAW), Beijing Platform for Action and Convention on Rights of the Child where the nation's commitment to protect and empower its women and girls is evident. India has been striving to dispel discrimination against women in all forms. Laws against sex selective abortion, child marriage and sexual harassment at workplace are being implemented. However, discrimination against women in India remains a deep-seated issue despite various policy and legislative reforms being undertaken at all levels. However, initiatives are being taken to prevent gender disparities at every stage, right from the time the fetus is placed in the womb of a mother to education, marriage to labour market posing significant barriers for the future of girls. Through committed implementation of government incentives/ schemes like Beti Bachao, Beti Padhao, awareness campaigns in the states, focus is on changing the mindset of people towards girl child. Implementation of SDG 5 will go a long way in making India gender equal. Though the discourse on gender justice and empowerment is rampant in our country, SDG 5 can help in bringing a gendered approach to the policies, schemes and laws of the country. India is expected to gain from its demographic dividend in the coming years and women are an integral part of this developmental process if India wants to tap its full potential. It is only through empowering the women in all forms that women will transcend beyond the constraints they presently face. It is essential to focus on these aspects if India wants to achieve SDG Goals by 2030.

Adolescent girls in the age group of 10-19 years constitute a significant 22.8% (232 million) of India's population (UNFPA, 2003). They face discrimination from their male counterparts on mobility, education attainment, say in decision making, nutritious meals, employment and marriage which impacts their physical and mental developments. Especially at this crucial stage of their life when they are transiting from childhood to maturity. During this phase they need physical, mental and emotional support from their siblings, friends, parents, family, neighbourhood and society. It is considered a critical stage for adolescent girls especially coming from the marginalised section of society as at this transition phase either they continue with secondary education, get married or enter into labour market. This decision is seldom the girl's choice but mostly dominated by economic factors, family decisions, societal and cultural factors.

Impact of Covid 19 Pandemic on Adolescent Girls

COVID-19 pandemic left millions of students at the risk of not returning back to school due to financial distress, help in household chores, childcare support, early and forced marriage, unintended pregnancy. It is estimate that about 24 million students (from pre-primary to tertiary education) will be at risk of not returning to education institutions in 2020, including care centres, schools, universities or other training institutions, of which 10.9 million are in primary and secondary levels. 11.2 million are girls and young women, with 5.2 million of them being primary and secondary school students (UNESCO, 2020). Table 1 provides an estimate of student dropouts by 2020 growth projections (growth projections are weighted by the student's cohort of each country and are weighted by Gross Domestic Product (GDP).

Particulars	Growth Projections 2020	Number of drop-outs (in millions of students)
MPO-March	-0.8	1.9
WEO-April	-2.3	4.1
MPO-May	-3.4	6.8

Table 1. Estimates of Students Drop Outs by 2020 Growth Projections

(Source: World Bank, Research Paper Series, 2020)

The figures above indicate that with every fall in the growth projections will lead to household income shocks and an increase in the drop outs. It is now even more worrisome as Covid 19 pandemic and induced lockdown has increased the gender gap in education posing more challenges for adolescent girls in continuing online education during economic hardships faced by their family. The economic impact of Covid 19 will increase the risk of early dropout as girls are more vulnerable to child labour, child marriage, violence and sexual abuse (UNESCO, 2020). Increased rates of poverty, household responsibilities, child labour, teenage pregnancy may prevent as many as 20 million secondary school-aged girls around the world from ever returning to the classroom (Malala Fund, 2020). Alongwith the prevailing norms this interruption in learning had a greater impact on girls than boys and disproportionately affected adolescent girls belonging to marginalised section of society and from families that lost their livelihood during the pandemic (RTE forum, 2020)

Thus, it is impertinent to include adolescent girls in policy making as it will be insightful to invest in this segment to build a strong economic base (Judith, 2007), promoting gender equality, reducing health issues (maternal mortality, infant mortality and HIV), eliminating child marriage and help in reversing intergenerational poverty.

Both, the lack of access to schools and economic hardships due to COVID-19 puts girls at a higher risk of gender-based violence and forced child marriage. In the wake of these problems the study proposes to understand the impact of school closure on girls and to understand the role of stakeholders in addressing gendered differential in the wake of third wave.

Objective of the Study

The objectives of the study are as follows:

(i) To understand the impact of school closure on adolescent girls amid Covid-19 pandemic.

(ii) To explore the role of stakeholders in addressing the issues raised by marginalized section of the society

(iii) To explore the measures required to mitigate the impact of Covid 19 on adolescent girls' education

Based on the research objectives the research questions are designed as follows:

a. What is the impact of school closure on adolescent girls amid Covid-19 pandemic?

b. Are the stakeholders/ policy makers ready to absorb the effects of the upcoming third wave?

c. What are the measures required to mitigate the impact of Covid 19 on adolescent girls' education?

The study was designed around the following critical areas of enquiry: (i) Social, demographic and economic profile of adolescent girls (ii) The impacts of the pandemic and school closure on the education and lives of adolescent girls between the age-group of 10-18 years, including how they spend their time in absence of schools and the status of access to and use of technology for learning (iii) The kind of support the household received from governments and civil society, especially in the context of income and livelihood losses and compensation for the loss of learning due to school-closure.

The sample of the study is collected from adolescent girls enrolled in a Centre of Excellence run by an NGO Protsahan India in Uttam Nagar, New Delhi. Population of the study constituted 416 adolescent girls belonging to the age 10-18 years from marginalized background. Primary data in the form of survey was conducted and response were collected by 100 adolescent girls through questionnaire to access their vulnerability on parameters of exposure and vulnerability mapping was developed from in-depth interviews and observations of 24 adolescent girls studying in the same center. In-depth interviews were conducted to understand their sensitivity and adaptive capacity used as parameters for vulnerability mapping. This field level empirical study was undertaken to from November 2021 till February 2022 when the schools in Delhi were in the transition of resuming physical classes. In-depth interview was conducted and questionnaire was also floated covering details about their education, age, death due to covid-19 pandemic, family members' profile and access to ration and Aadhar card.

Protsahan India Foundation is a non-profit organization established in 2010. They work against any form of child abuse and for the betterment of at-risk adolescent girls in the underserved

communities of India. The slum neighborhoods where Protsahan is currently working, adolescence or hitting puberty is considered to be the age for getting the girls married irrespective of the fact that neither their mind, nor body are developed to handle such responsibilities and their consequences. They aren't even considered worthy of an education. Girls in this underserved community, as others, face all forms of child abuse on a daily basis. Some come from families where they go to sleep after witnessing domestic violence and alcohol abuse every night; some have 7-10 members living in the same room, as a result of which they have grown up in distorted environments which have left them with a warped sense of boundary, experiencing direct scenes of extreme intimacy or violence between parents; some have been sexually abused by one of their family members; and some are trying to get away with the constant pressure of becoming a child bride. There is no understanding of menstrual hygiene, reproductive health or nutrition. As a result, they are at high risk of early pregnancies, sexually transmitted diseases, stunted physical growth, and overall hampered health and development.

Vulnerability Mapping of Adolescent Girls: Risk, Sensitivity and Adaptive Capacity

Vulnerability of adolescent girls are assessed based on their poor and economic living conditions, government (both central and state) aid/linkages and medical aid. Vulnerability is commonly associated with poor economic and nutritional status, but many other overlapping social vectors such as quality of housing and public services, occupation, gender, disability, marital status, age, stigmatized and debilitating ailments and many other aspects are not recognized (National Urban Health Mission, 2017).

Vulnerability is a multidimensional process affected by social, political, and economic forces interacting from local to international scales (Bohle, Downing, & Watts, 1994; Ribot, 1995). Vulnerability is a function of exposure, sensitivity, and adaptive capacity (Engle, 2011; Smit and Wandel, 2006). Many factors influence vulnerability, four broad spectrums: access to resources, governance, culture and knowledge have been considered in the past to understand the social aspect of vulnerability. Together they provide a comprehensive, interdisciplinary social science framework for analyzing and understanding uneven vulnerability across social difference. So, vulnerability mapping entails mapping of exposure, sensitivity and adaptive capacity indicators where greater the exposure or sensitivity of a system means greater the vulnerability (Esterhuyse et al., 2017). The study has been conducted on the basis of the framework proposed by Thomas et al in 2018, though it was used in climate study the vectors can be applied to other disciplinary studies as well.

Fig. 1. Vulnerability Assessment: Framework



(Source: Engle, 2011; Thomas et al. 2018)

Vulnerability is a function of exposure, sensitivity and adaptive capacity so it can be stated as Vulnerability = function (exposure, sensitivity and adaptive capacity). Exposure (external characteristic) is the risk of being allowed or forced to experience something and in the context of the study it poses the risk adolescent girls are of discontinuing formal school education.

She is exposed to risks from various peripherals stated in fig. 2 starting with own parents, siblings, extended family, neighborhood, friends, society and culture. During adolescent, as the girl undergoes transition and experience changes in appearance, though process she either isolates herself and keep her interactions with people she is comfortable like parents, siblings and friends or she explores her surroundings and periphery of her interactions expands beyond personal relationships. Mostly the decisions related to her studies, marriage and future are taken by her immediate family taking into considerations societal norms.



Fig. 2 Periphery in Exposure of Adolescent Girls

(Source: Self Compiled by the author)

Sensitivity (internal characteristic) is the degree to which these adolescent girls are affected by the exposure to risk of discontinuing their formal school education. For the purpose of this study sensitivity is studied on a scale of 1-5 where 1 is least sensitive, 2 is less sensitive, 3 is moderate sensitive, 4 is more sensitive and 5 is most sensitive. When a girl is ranked 1 based on the indepth interview it means she is not affected by and face challenges at ease and if a girl is ranked 5 it means she is very sensitive to the new environment/ change and it is having an impact on both her mental and physical well-being. The scope of study was limited to understanding the intensity of impact on sensitivity on the scale and not in profound depth but it can be considered in future to cover this aspect in detail.

Adaptive capacity is the ability of these adolescent girls to develop resilience and adjust to the changing situation. Physical changes along with exposure to situations of discontinuing studies, early marriage, enter the labour market and others might have a deep impact on the girl undergoing it. These sudden changes might traumatize her and have a deep impact on her present and future. These impacts are based on factors like income level of family, support of family, education level of family, support of NGOs and government.

High vulnerability situation is when adaptive capacity is low, relative to exposure and sensitivity. Contrarily, if the adaptive capacity is high it helps in reducing the effects of exposure and sensitivity, and in turn reduces vulnerability. (Thomas et al., 2018)

Interview schedule was prepared and used during the mapping process and the adolescent girls belonging to marginalized sections were dealt in very subtle manner and it took time to collect data from these girls. Initially, the data was collected based on questionnaire and during data collection the response of these girls were recorded and to understand the exposure and sensitivity towards vulnerability interviews at length were conducted. The team focused to understand the reasons of these adolescent girls for discontinuing education during the Covid-19 pandemic and access their willingness and ascertain the problems faced by both the girl respondents and their family. Vulnerability was classified in three categories as stated in Table 2.

Table 2. Vulnerability Indexing

Vulnerability Index	Score	Condition
Vulnerability	1	If any One condition is met
High Vulnerability	2	If any Two conditions are met
Extremely High	3	If Three or more conditions are met
Vulnerability		

(Source: Self compiled with Protsahan India team)

Above stated vulnerability index was calculated based on the score (1-3) where the respondent is marked vulnerable if any one condition stated in Table 3 is met, the respondent will be marked as highly vulnerable if any two conditions stated in the below table are met and if a respondent scores 3 it means she is extremely vulnerable if three or more stated conditions are met.

Table 3 states the conditions to access vulnerability index of the respondents

Conditions to access vulnerability index	Status
Family Income (for a family of 5)	<rs 10,000="" month<="" per="" td=""></rs>
Basic Documentation (Aadhar card, PAN	Not available
card, Labour card, E-shram card and Ration	
Card)	
Basic Healthcare	Not able to access
Basic education for the children	Not able to access
Linkages to government schemes	Not able to access
(Aaganwadi, Laadli Scheme and any other	
government scheme)	

(Source: Self compiled with Protsahan India team)

These conditions were compiled based on the spectrums like access to resources, governance, culture and knowledge have been considered in the past to understand the social aspect of vulnerability. Thus, conditions to access vulnerability index were developed based on respondents demographic profile like family income, basic documentation (Aadhar card, PAN card, Labour card, E-shram card and ration card), basic healthcare, basic education for the

children, beneficiary of any government scheme (like aanganwadi, laadli scheme or any other government schemes).

Demographic Profile of Respondents

63% adolescent girls belonged to the age category of 10 to 15 years and 37% were in the age category 15 to 19 years. Majority constituting 54% respondents hailed from Bihar followed by 27% from Uttar Pradesh, 15% from Rajasthan and merely 5% from other states.

85% of the respondents belonged to a family of 5 and more members, 13% were family of 4 and remaining 2% belonged to a family of three and less. Whereas the earning members of the family were solely 1 in case of 58% respondents, 30% cases had 2 earning members in their family, 9% had 3 earning members and 3% respondents had 4 and more earning members in their family. Such large families with few earning members tend to detrimentally impact the nutritional and educational outcome of children (Kugler et al, 2017).



Fig. 3. Primary occupation of parents

(Source: Self compiled based on primary data)

Only 52% respondents' fathers were in employment (mostly informal sector working in construction sites, sweeper, rickshaw drivers and rag pickers) remaining 28% were unemployed and 20% were beggars. 48% respondent's mothers were employed as domestic helpers and daily wage laborer, followed by 32% who were housewives and 20% were beggars. It reflects the vulnerable position of these adolescent girls, especially at this time of pandemic when economic activities were allowed only in essential services and other arenas were restricted or suspended. Further investigating into data stated the vulnerable condition of these adolescent girls in terms of monthly earnings as stated in Table 4 reflecting that 75% adolescent girls don't have access to

resources with majority coming from households where monthly earning is less than Rs 8000 per month prior to Covid 19 pandemic and during the pandemic approximately 75% respondents either parent lost their job.

Particulars (per month)	Responses
Less than Rs 5,000	31
Rs 5,001 to Rs 8,000	44
Rs 8,001 to Rs 10,000	16
More than Rs 10,001	8

Table 4. Family income of respondents

(Source: Self compiled based on primary data)

These situations could likely have bearing on continued schooling of these girls during resource deprivation exacerbating their vulnerability (Jha and Jhingran, 2006 and Usaini, M. et al, 2015). Migration is also an area of concern and especially during this period when statistics obtained from studies also suggested that almost only 4% of the total population of the migrants received rations that were allotted by the government, and 29% did not receive rations despite having ration cards (Farooqui and Pandey, 2020). Almost 90% of the migrants either faced loss of pay or a reduction in their salary (Shahare, 2020). International Labour Organization (ILO) estimated a decline of 22.6% in the wages of migrant workers post lockdown (Gothoskar, 2021). A survey conducted across 179 districts in India from May 30, 2020 to July 16, 2020 found that around 35% of the migrants went without any meal the whole day (Pandit, 2020). Migration poses major challenges for education systems in normal circumstances (GEMR, 2019) so it can be projected with reverse migration it would have been difficult for students (especially adolescent girls with burden of sharing household chores) to continue their studies in challenging times when either or both parents were struggling to retain their job. 13% respondents broke down when they informed they lost their father's life to Covid-19 and it was either their mother who were currently working to support the family or elder sibling (brother or sister), if any.

79% respondents reported having inadequate food to feed the dependent members of the families. School-going children, who were at home during lockdown did not had access to midday meals indicating higher incidences of hunger and malnutrition. Adolescent girls faced discrimination in nutritious meals being provided of inferior quality from their male counterparts in normal times and when struck with pandemic their nutrition was neglected. Majority girls felt the discrimination happening with them in terms of nutritious food and they showed the desire to join school, one reason being the mid-day meals provided to them. In the case of the school-going girls, this only gets heightened given the nutritional discrimination they face.¹² It tends to have an impact on these growing girls and many accepted the discrimination and were satisfied seeing their brothers being fed nutritious meals and they being deprived. This is not a good sign as if these girls are accepting this discrimination, it won't take much time for them to think it to be

¹² (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4167551/)

normal and follow it in future with their children as well. It will definitely have a repercussion on the upcoming generation as well.

Despite central-government funded schemes and included Jan-Dhan Yojana, Pradhan Mantri Ujjwala Yojana, Pradhan Mantri Garib Kalyan Yojana, Building and Construction workers welfare fund and PM Kisan Samman Nidhi and others. These respondents were not enrolled in any of the schemes and they were only partially aware of the schemes run by government.

80% respondents lived as a tenant and only 20% owned the home they were presently living or lived with a close relative/ acquaintance. Merely 48% had access to toilet with proper waste disposal reflecting these girls did not even have a safe and hygienic toilet which is a necessity especially when these girls are in menstruation phase exposing them to diseases and exploitation. 88% respondents had access to mohalla clinic for primary healthcare and 12% still didn't had access to primary healthcare. Of which, 77% respondents had access to life saving immunizations and 23% did not had access to these immunizations.

Findings and Observation

It was observed that majority of adolescent girls who were associated with Protsahan India even for less than a year experienced change in terms of confidence, ambition, resilience and sense of independence. Protsahan India worked at ground level and filled the void that remained despite the presence of central and state government. Prime Minister Narendra Modi called on Non-Government Organizations (NGOs) to help the government by providing basic necessities to the underprivileged and continue supporting vulnerable populations.

In their almost a decade of work, the outcomes of their programs have been incomparable. All of the girls enrolled at their Centre of Excellence (CoE), who have appeared for their board exams, have cleared with excellent scores, some scoring as high as 80-90% in most subjects. 88% of the girls that they currently work with have not only been able to receive higher education, but have also shown an improvement in their annual school scores.

During lockdown the work done at the grass root level by Protsahan India team was commendable they provided rations to more than 26700 households in Delhi slums, provided resources at their centres to be accessed by the adolescent girls when their schools were closed and they did not had access to resources to continue their online classes, provided counselling to adolescent girls and their families. They also raised alarm through their reports of heightened cases of violence against children and adolescent girls and tried to reach out to girls and their families in times od distress and provide them with essential resources. During lockdown the team distributed simple relief kit consisting of need based customized assortment of 10 kg flour, 10 kg rice, 4 kg pulses, 2 kg potatoes, 2 kg onions, salt, sugar, essential spices, tea, biscuits and sanitary napkins.

Protsahan India Foundation has developed their model of work as the HEART principle (Healing, Education, Art based Life Skills, Recovery and Technology) that is based in the premise of working through the power of empathy, creativity, life skills, and active listening. Their focus is on healing the broken childhoods using the creative power of various art forms like painting, cinema,
design, film making, dance, music, photography and meditation and helping the girls with their education through an integrated after school program.

Having a model of work as the HEART principle based on trauma informed compassionate care, Protsahan India Foundation aims at addressing the adolescent girl framework for achieving their ultimate goal of fighting child abuse and healing and empowering girls. They want their girls to thrive, learn, have access to clean environments, and be protected from violence and exploitation.

Vulnerability Mapping

Exposure

53% respondents were engaged in earning activity like begging, child labour and sex work prior to enrolment in Protsahan and 47% were not enrolled in any earning activity. 20% respondents shared that they have risk of child marriage and remaining 80% respondents didn't feel the risk of child marriage.

Mere 46% respondents received 3 nutritive meals a day at home and 54% did not receive these 3 nutritive meals. 72% respondents experienced domestic violence at home and only 28% did not experience domestic violence at home. 59% respondents were at high risk of sexual abuse and remaining 41% were exposed to moderate, low and no risk of sexual abuse. 64% respondents were of the view that they did not get ample time to study and only 36% got ample time to study.

Sensitivity

It was interesting to notice that initially majority of girls didn't notice that they were sensitive to the discrimination they were facing but after the interactive sessions these girls opened and, in the discussions, almost all showed dissatisfaction towards the discrimination they had to face. They were keen to return back to formal schools but being aware of the resource constraints and the problems faced by their families they were ready to follow their parents decision. It was also observed that many girls developed a negative attitude and reluctance for participation in any group activity.

Adaptive Capacity

In the given timeline and resource crunch it was not feasible to reach out to all the girls supported by Protsahan India team but we tried to understand how the team is reaching out to these girls and improving the adaptive capacity so that these girls continue their education.

2442 adolescent girls and their families identified in the group of vulnerable to highly vulnerable category were supported by Protsahan during Covid-19 (2020 and 2021) in West Delhi. Of these 902 girls fall in the category of extremely high vulnerability and 238 comprising 26.4% adolescent girls were supported by Protsahan and were enrolled in their GEC and 73.3% girls were supported by the team despite they not enrolled in their GEC stated in fig. 4.



Fig. 4. Adolescent Girls Supported by Protsahan India Team during Covid 19 Lockdown

(Source: Self compiled with the data shared by Protsahan India)

The support extended to vulnerable adolescent girls by Protshan India during and after lockdown are as follows:

- (i) Nutrition and healthcare support Ration rich in protein content
- (ii) Linking the unlinked with government schemes (either Central or State)
- (iii) mainstreaming the marginalized girls with access to digital divides
- (iv) Academic and life support skills to girls (counselling to girls exposed to violence)
- (v) Scholarship for vulnerable girls
- (vi) Enrolment in STEM courses
- (vii) Cowin registration and vaccination drives in slums
- (viii) Fellowship program for employability enhancement of younger girls

Protsahan India Foundation follows a "Trauma-Informed Compassionate Classroom" model that includes Creating A Safe Space For Socio-Emotional Development, Building A Sense of Trust and Empathy, Establishing Predictability and Academic Rigor, Offering Choice Based Creative

Arts Options, and Steering the Child Towards Socio-Economic Stability. It deals with at-risk adolescent girls who are (have been) dealing with various levels and types of trauma and therefore adopted its current trauma-informed care approach in order to 'heal' them. The organization believes in a "Theory of Change" that rests on three pillars:

Empathy - It involves delivering emotional and psychological support, complemented with support in formal school education, enables young adolescents' girls to be empowered to take charge of their own lives.

Creativity - Creativity of art, theater, dance, music, film-making, and photography not only provides healing for the childhoods broken by abuse, but also ensures improved long term learning outcomes in formal school education, and a better quality of life through higher self-confidence for young adolescent girls.

Life Skills - Life Skills training needs an ongoing systematic approach towards imparting soft skills and entrepreneurial skills that have a direct impact on the life of an at-risk young adolescent girl. It is essential to ensure that the girls understand the importance of their voice and their thoughts in everyday life situations. Life skills training includes personal safety education (good touch bad touch and training against child sexual abuse), critical and creative thinking, everyday problem solving and decision making, effective communication and social skills, interpersonal relationships, coping with emotions and stress, self-awareness and self-worth, greater participation in governance, entrepreneurship development, leadership building and social enhancement, ease of accessing digital services, awareness of rights and entitlements, financial inclusion, mentorship and career counselling.

Proposed Framework to Help Vulnerable Adolescent Girls

Based on the observations and data collected during the study a framework stated in fig. 5 was proposed to address the issue of gendered differential impact of school closure on adolescent girls. The framework constitutes major steps to access vulnerability of these girls in terms of exposure to risks by the internal surroundings (their parents, friends and family) and external surroundings (neighbors, society and culture), sensitivity (high or low) and adaptive capacity measures to be taken together by the stakeholders (their family, NGOs, institutions, society and government) to help these girls in overcoming the barriers in joining back the school. With the help of NGOs working with adolescent girls' government can include inputs collected by them, understand and incorporate measures to provide equal rights to these girls and not let them drop school in the dearth of resources and societal norms. If timely action is taken then we can together bring these girls back to school, improve the drop rate of girls in secondary education, empowering these girls and achieve SDG Goals by 2030.

Fig. 5. Proposed Framework



(Source: Self compiled based on the outcome of the study)

Conclusion

The existing societal norms, structural barriers of caste and stigma towards adolescent girls' education poses a threat of reversing the visible gains made in terms of gender parity in education and empowerment. The gendered impact of the pandemic on education of adolescent girls (in terms of high-risk exposure and limited means) can have a deep-rooted impact on the coming generations if this concern is not addressed comprehensively. This discourse can be addressed to a great extent if corrective measures are timely responded by understanding the root cause of the problems faced by adolescent girls and their families and responding to their specific needs and ensuring its inclusion in the policies framed by government. We have to reach the SDG goals in the stipulated time period and it will only be achieved by filling the void and adopting an effective framework to help marginalized families in distress, especially on economic front in order to prevent child marriage, children entering the labour market and discontinuing the school.

The study identified various challenges faced by the girls in their adolescent at the wake of the pandemic, when they are out of school. These challenges are infrastructural barriers, genderbased discrimination, exposure to abuses, child marriage and sexual exploitation within and outside their home. The study suggests towards the long-term impact on these adolescent girls. School closure is not only impacting the girls currently but also highlights that if corrective measures are not put into practice, it would surely have an impact on the entire generation. The study also covers the measures adopted by government to address this issue; however, it states that not much is done for this vulnerable group and also leaves few questions to be answered by the stakeholders: Are we prepared to help the adolescent girls join back the school? What remedies are we providing to these girls belonging to marginalized section? What measures are being taken by the stakeholders to help this entire generation overcome the problems related to school closure? So, the question still remains the same that despite the aids provided by the government and individuals, such sensitive issue needs to be highlighted and timely corrective measures needs to be taken seriously to get these girls back to school or it will definitely have an impact on the entire generation. A holistic approach needs to be taken by the stakeholders to ensure educational equity and inclusive environments to fill the void for these vulnerable girls.

Acknowledgement

This study would not have been possible without the support of Protsahan India and its staff members working with adolescent girls and their families.

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Diarrheal Diseases and Evaluation of Inhabitants' Knowledge, Attitude and Practices regarding Water Safety, Sanitation and Hygiene in Cholera Endemic Localities of Douala, Cameroon

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Abstract

Purpose: In Cameroon, about 3.8 million people lack access to safe water and sanitation facilities. Frequent outbreaks of diarrhea diseases, particularly cholera, a diarrhea disease caused by *Vibrio cholerae*, occur in Douala due to inadequate water, sanitation and hygiene (WASH). This has qualified the city of Douala as a cholera-endemic area. Recent outbreaks in Douala have increased in size.and occur towards the end of the dry season. This study determined the prevalence of diarrhea and evaluated inhabitants' knowledge, attitude and practices (KAP) regarding WASH in cholera endemic localities of Douala.

Design/methodology/approach: A community-based cross-sectional survey was conducted between July and September 2017 in three health districts: New Bell, Nylon and Deido, to evaluate inhabitants' KAP, and diarrhea prevalence. A retrospective hospital-based study was conducted to determine diarrhea prevalence from 2011-2015. The Chi Square and multivariate regression were used to analyze data.

Findings: Prevalence of diarrhea in community-based study (17.9%) was higher than 11.1% in the retrospective study. Overall, good KAP (mean score of \geq 50% for knowledge and attitude and \geq median score for practices) was observed respectively in 38%, 66% and 80% of respondents. Participants with good knowledge (p=0.066), good attitude (p=0.011) and good practices (p=0.084) on WASH were less likely to have diarrhea than those with poor knowledge, poor attitude and poor practices. However, a significant association was observed only for good attitude.

Originality/Value of the paper: This study has identified gaps in KAP and show that there is an urgent need for interventions to enhance behavioral change to prevent WASH-related diseases and promote health. Data generated could be used to monitor Cameroon's progress towards the attainment of SDG 3, SDG 6 and SDG11. The research team intends to collaborate with the Douala Municipality and public health authorities to ensure improvement in WASH and behavioral change.

Keywords: Diarrhea; Knowledge, Attitude and Practices; Water, Sanitation and Hygiene, Douala, Cameroon

Purpose

Diarrhea disease is a global public health problem. It is a threat to health security and a developmental challenge. Global estimates show that in 2016, diarrhea was the eighth leading cause of death claiming over 1.6 million lives, the fifth leading cause of death among children under 5 years and the third cause of disability-adjusted life years (DALYs) (Global Burden of Disease (GBD) 2016 Diarrhea Disease Collaborators, 2018). Diarrhea was the second leading cause of mortality and the leading cause of malnutrition in children under 5 years old in 2017 (WHO, 2017a). The highest burden of diarrhea occurs in low-and middle-income countries (GBD 2016 Diarrhea Disease Collaborators, 2018; UNICEF, 2016), where it disproportionately affects individuals in the low socioeconomic index group. The highest burden occurs in children 5 years and below (Manetu et al., 2021; UNICEF, 2021), accounting for 63% of the global burden due to diarrhea (Zhang et al., 2016). Although global statistics show a significant decline in mortality due to diarrhea, from 1.2 million to 526,000 between 2000 and 2015 (GBD 2016 Diarrhea Disease Collaborators, 2018; UNICEF, 2016), morbidity and mortality due to diarrhea are still a serious concern in low- and middle-income countries (GBD 2016 Diarrhea Disease Collaborators, 2018), particularly in sub-Saharan Africa and south Asia, where there is lack of resources and inadequate infrastructure for diarrhea disease management. In Africa, the burden due to diarrheal disease remains high; there were about 30 million cases of severe diarrhea and 330, 000 deaths in African in 2015 (Reiner et al., 2018).

The occurrence of diarrhea and associated deaths have been linked to lack of clean water, inadequate sanitation and poor hygiene (GBD 2016 Collaborators, 2018; Soboksa et al., 2021; Getahun et al., 2021). Diarrhea diseases caused by unsafe drinking water and poor sanitation were identified as the top two leading risk factors resulting in mortality globally for individuals aged five years and under in 2017 (GBD 2017 Collaborators, 2018). About 88% of diarrheal associated deaths are attributable to unsafe water, inadequate sanitation and insufficient hygiene (CDC, 2020). In addition, water, sanitation and hygiene (WASH) have been linked to the spread of neglected tropical diseases (NTDs), adverse health outcomes such as stunting, wasting and underweight, and social outcomes (WHO, 2017b, WHO, 2021; Pickering et al., 2015; Cumming and Cairncross, 2016; Mbuya and Humphery, 2016; Mills and Cumming, 2017), hence constituting a developmental challenge as it affects the progress towards the attainment of other Sustainable Development Goals (SDGs). Multi-country studies by Fuller et al. (2015) and Esrey et al. (1996) have reported larger impacts on health following concurrent improvement of water and sanitation compared to improvements on water or sanitation alone. Despite the enormous data underscoring the importance of WASH in mitigating the occurrence of diarrhea diseases as well as other waterborne diseases, access to WASH is still a problem in some parts of the world. Global statistics demonstrate an overall increase in access to improved water and sanitation in low-middle income countries (LMICs) between 2000-2017, but this improvement is still very insignificant in sub-Saharan Africa where access is concentrated mainly in urban areas than in rural areas (Local Burden of Disease WASH Collaborators, 2020).

Safe water and sanitation, which contribute to appropriate hygiene, are fundamental determinants of individual and social health and well-being (Bolatova et al., 2021) as they are of paramount

importance in the prevention of waterborne diseases including diarrhea. Knowledge, attitudes, and practices (KAP) is one of the corner stones in the fight against a disease as it permits the identification of misconceptions which when addressed will contribute to disease prevention and control. Lack of knowledge, attitude and practices (KAP) is one of the major contributors to the transmission of infectious diseases (Dreilbelbis et al., 2013). Thus, even if appropriate WASH facilities are provided and there is poor compliance due to inadequate KAP, diarrhea disease will continue to occur. This is because access to WASH alone without adequate compliance is ineffective in mitigating health problems associated to unsafe water and poor sanitation and hygiene (Barnard et al., 2013). Thus, since an adequate KAP with regards to WASH are of paramount importance in the prevention of diarrhea diseases, it is necessary to evaluate KAP on WASH to identify gaps which must be addressed so as to achieve a sustainable and effective implementation of WASH programs in communities.

Cameroon, a central African country located in the Gulf of Guinea, bordered by Nigeria to the west and north; Chad to the northeast; the Central African Republic to the east; and Equatorial Guinea, Gabon and the Republic of the Congo to the south, has, over the years, received support on WASH from its partners (Reach Initiative, 2019; Manah, 2014; OCHA, 2022). Even with this, access to WASH is still a challenge particularly in the rural parts of the country and urban slums. According to the United Nations SDG Goal #6: Clean Water and Sanitation snapshot, 79% of the population of Cameroon used safely managed drinking water services, 60% used improved sanitation with 6% practicing open defecation, while 36% had a hand-washing facility with soap available (UN, 2020). This shows that although there is progress in safe water, sanitation and hygiene are still a problem. Frequent outbreaks of cholera occurring in Cameroon indicates that inadequate access to WASH is a public health concern. Recent cholera outbreaks in various parts of Cameroon have been related to poor sanitation (WHO, 2021). The National Health Development Plan (NHDP) of Cameroon for 2016-2020 (MoH, 2016) recognizes low access to potable water, poor hygiene practices and waste management as key health determinants in Cameroon. Studies conducted in various parts of the country have reported a high prevalence of waterborne diseases (Lontuo-Fogang et al., 2021; Gorham et al., 2017; Djaouda et al., 2020) showing that there is an urgent need to address WASH in Cameroon.

Douala, a coastal town and the Economic capital of Cameroon has experienced a rapid, unplanned and unmanaged urbanization due to an influx of rural dwellers in search for employment opportunities. In addition, the socio-political crisis in some parts of the country that started in 2016 has forced people to flee to Douala (and other cities) for safety, further swelling the population. This has placed a heavy burden on the limited WASH infrastructures in Douala. Hence, Douala continues to experience outbreaks of waterborne diseases, particularly cholera despite the WASH interventions carried out. The effectiveness of WASH in diarrhea disease reduction depends on the provision of WASH infrastructure and compliance of individuals. This was observed in a collaborative study in Bamuso Health District between the University of Buea and Plan International, Cameroon (Akoachere, 2015). The present study was therefore aimed at evaluating the prevalence of diarrheal diseases and its association with inhabitants' KAP regarding WASH in three cholera endemic localities of Douala, Cameroon, in a bid to identify interventions needed to prevent diarrhea and promote health in these localities. Furthermore, the

findings of this study may contribute to efforts to monitor Cameroon's progress towards the achievement of the UN Sustainable Development Goals, particularly SDG #6 and #3: Good Health and Well-being.

Design/Methodology/Approach

Study Area and Design

This study was carried out in three health districts in Douala, Cameroon: New Bell, Nylon and Deido. Douala is the economic capital of Cameroon and the county's main port. This coastal city lies between Latitude 4°2'N to 5°4' N and Longitude 9° 9' E to 11°5' E and has an estimated population of over 3.9 million inhabitants (World Population Review, 2022) with an annual growth rate of 3.51%. Douala has an average annual rainfall of 3174 mm and average annual temperature of 26.9°C (Climate-Data.org). It has an equatorial climate of two seasons: the dry season which runs from November to April, with January and February being the hottest months, and the rainy season which lasts from May to October (Climate-Data.org). The months of July, August and September have the highest rainfall in Douala. The city has poor drainage due to poorly constructed drainage system which often get blocked as a result of arbitrary refuse dumping, and causes flooding after heavy rains. Douala lacks a sewage system and sewage treatment facilities hence untreated sewage is discharged indiscriminately into the environment (The New Humanitarian, 2004). The three health districts which are the focus of this study: New Bell, Nylon and Deido were purposively selected because they are cholera hotspots in Douala (Ateudjieu et al., 2019).

This was a quantitative community-based cross-sectional study conducted between July and September 2017, and a retrospective hospital-based cross-sectional study, involving a review of patients' records for diarrheal cases from 2011-2015, in one major health facility in each of the three health districts. This study was conducted in the Department of Microbiology and Parasitology, University of Buea, in partnership with the Littoral Regional Delegation of Public Health.

Sample Size Determination

The sample size was calculated using the formula for estimation of single proportion (Berhe et al., 2020). An anticipated population proportion of 0.5 (50%) was used since the population proportion was unknown. Absolute precision (i.e. margin of sampling error) tolerated was set at 5%, at 95% confidence interval, using the formula: $n = Z^2_{1-\alpha/2} [P (1-P)]/d^2$

Where

n = sample size, P = Population proportion = 50% (0.5), q = 1 – p (1-P) = 1- 0.5 = 0.5 d²= margin of sampling error tolerated at 95% confidence interval = 5%. Hence, n = $(1.96)^2 \times 0.5$ $(1-0.5)/(5)^2$, n = 368.00. Adjusting for non-compliance rate (Maumita and Pranita, 2016) of 30%, noncompliance = $30/100 \times 368.00 = 110.40$. Thus, the adjusted sample size = 368.00 + 110.40 = 478.40. Working sample size ≈ 480 subjects. Accounting for a design effect of 1.5, gave 1.5 x 480 = 720 subjects as minimum sample size.

Sampling Technique

In the community-based study, three health districts in Douala: Nylon, New Bell and Deido were purposively selected based on their history of cholera outbreak. In the district of Deido, Bepanda health area was selected purposively because of its high cholera attack rate during cholera outbreaks. In Nylon and New Bell, simple random sampling was used to select participating health areas. Four out of ten health areas in New Bell (Camp Yabassi, Youpwe, Kassalafarm and Nkololoun) and three out of seven health areas in Nylon (Tergal, Oyack, and Madagasca I) were selected. In Bepanda health area, 3 out of six quarters (Bepanda TSF Cacoa Barry, Bepanda TSF and Bepanda Voirie) were selected.

Those included in the community-based study were household heads, male or female adult adults responsible for the organization and care of the household (or a representative \geq 21 years when household head was absent), who granted consent and has been living in the study site for more than one year. For the retrospective study, all patients who sought care in the selected health facilities, had diarrhea as diagnosed by a clinician and were residing in study health districts were recruited.

Data Collection

Data was collected using a pre-tested structured questionnaire and an on-the-spot observation checklist. The structured questionnaire was prepared in English and translated to French, as French is the most widely used language in Douala. The questionnaire was adapted from relevant literature (Pachori, 2016; Shriya et al.,2014; Sah *et al.*, 2015; Rima et al., 2017). It consisted of five sections: Section A captured information on the socio-demographic characteristics of participants; Section B, knowledge on WASH; Section C, attitudes towards WASH; Section D, practices on WASH, while section E had questions on diarrhea occurrence. Occurrence of diarrhea was defined as having loose or watery stool at least three times in 24 hours period one month prior to the survey, as reported by the respondent. The questionnaire included several close ended questions which helped to evaluate participants' knowledge, attitude and practices on WASH. An observational checklist was also used to evaluate WASH facilities, compound cleanliness, excreta and refuse disposal. Three research assistants were recruited and trained to assist in data collection. The training was on the objectives of the study, content of the questionnaire, approaches to be used during data collection and how to double check filled questionnaires.

In the retrospective study, data on diarrhea was obtained by reviewing patients' hospital records for diarrhea as diagnosed by a physician in selected health care facilities in the study site. Data of patients who sought health care from 2011-2015 was collected using a data capture form. The socio-demographic characteristics of the patients were also recorded.

Data Entry and Analysis

Data was entered into Microsoft Excel and Epidata version 7 and analyzed using the statistical software SPSS version 20. Descriptive statistics were employed to analyze participants' KAP on WASH. The Chi square test was used to analyze the association between diarrhea occurrence, socio-demographic factors and KAP of respondents. Multiple logistic regression analysis was used to investigate the association between good KAP and socio-demographic factors and an association between KAP and diarrhea occurrence. P-values less than 0.05 were considered significant.

To evaluate KAP on WASH, respondents, were required to provide either "yes"/"no" responses or to select a response from options provided. Each correct response on knowledge, attitude and practices was assigned a score of one (1) and an incorrect response was assigned a score of zero (0). For those questions in which participants had to select a response from options provided, a score of one (1) was assigned to a correct response and zero (0) to an incorrect response. A composite score was calculated for knowledge and attitude, and respondents ranked into two categories based on the mean value: good knowledge and good attitude for those who scored above the mean (50-100%), and poor knowledge and poor attitude for those who scored below the mean (<50%). With regards to practices on WASH, since data was not normally distributed, the median was used as the cut-off point. Those who scored less than median scores were classified as having poor practices on WASH while those that scored equal-to or more than median scores were classified as having good practices.

Ethical Considerations

Ethical approval of the study was obtained from the Faculty of Health Sciences Institutional Review Board of the University of Buea (Ref. 2017/027/UB/SG/IRB/FHS). Administrative approval was obtained from the Regional Delegation of Public Health for Littoral Region (Ref. 1551/AAR/MINSANTE/DRSPL/BCASS) and from the District Medical Officers of the respective study districts. Verbal permission to work in the selected communities was obtained from the Quarter Heads of those areas. The purpose of the study was explained to the participants. Participation was voluntary. Participants indicated their willingness to participate by signing an informed consent form.

Findings

Socio-demographic Characteristics of Retrospective Study Participants

A total of 7,884 patients' records were reviewed. This comprised 3,037(38.5%) from Despansaire Catholique Barcelone in Nylon health district, 2,315 (29.4%) from CMA Nkololoun in New Bell health district and 2,532 (32.1%) from CMA Bepanda in Deido health district. The majority of participants were female (57.8%), 1-5 years old (18.6%) and consulted in the year 2013 (26%) (Table 1).

ndicator Categories		n	(%)
CMA Nkololoun (New Bell)		2315	29.4
Health facility (Health	CMA Bepanda (Deido)	2532	32.1
Area)	Despansaire Catholique Barcelone	3037	38 5
	(Nylon)	3037	50.5
Gender	Female	4558	57.8
Gender	Male	3326	42.2
	Bepanda	2532	32.1
	Camp yabassi	295	3.7
	Kassalafam	362	4.6
	KM5	256	3.2
	Madagasca1	251	3.2
	Makae	73	.9
Health areas	New bell bamileke	745	9.4
nealli aleas	Ngangue	42	0.5
	Nkolmitag	34	0.4
	Nkololoun	474	6.0
	Nkongmondo	27	0.3
	Oyack	1597	20.3
	Tergal	1203	15.3
	Youpwe	6	0.1
	<1Years	147	1.9
	1-5	1463	18.6
	6-10	672	8.5
	11-15	474	6.0
	16-20	628	8.0
A we note warined	21-25	914	11.6
Age categorized	26-30	852	10.8
	31-35	558	7.1
	36-40	397	5.0
	41-45	302	3.8
	46-50	262	3.3
	50+	1215	15.4
	Business	974	12.4
	Civil Servant	143	1.8
	Informal sector	862	10.9
Occupation of the	Student	1626	20.6
Patients	Retired	212	2.7
	Infants	1042	13.2
	Housewife	1540	19.5
	Pupil	1137	14.4

Table 1 Socio-demographic Characteristics of Retrospective Study

Indicator	Categories	n	(%)
	None	336	4.3
	Farmer	12	0.2
	2011	1175	14.9
	2012	1387	17.6
Year of consultation	2013	2051	26.0
	2014	1793	22.7
	2015	1478	18.7
Total		N=7884	100

N=Total number of participants; n=number of participants per category; %=percentage

Socio-demographic Characteristics of Community Participants

A total of 738 household heads participated in this study. The majority were female (66.7%), age 21-30 years (47.3%), had attained secondary education (52.3%) and were from New Bell (49.1%). Over half of the participants lived in rented houses (51.5%) of size 1-3 rooms (76.6%) and the majority had a household size of 4-6 persons (44.4%) (Table 2).

Table 2: Socio-demographic Characteristics of Participants (N=738) from VariousCommunities

Indicator	Categories	n	(%)	
	Deido	196	26.6	
Health District	New Bell	362	49.1	
	Nylon	180	24.4	
	Bepand TSFCacao Barry	59	7.9	<u> </u>
	Bepanda TSF	57	7.7	
	Bepanda voirie	80	10.3	
	Camp yabassi	70	9.5	
Quertere	Kassalafarm/KM5	131	17.8	
Quarters	Madagasca 1	60	8.1	
	Nkololoun	22	3.0	
	Oyack	56	7.6	
	Tergal	64	8.7	
	Youpwe	139	18.8	
	21-30 years	349	47.3	
A a a	31-40 years	188	25.5	
Aye	41-50 years	88	12.0	
	>50 years	113	15.3	
Condor	Female	492	66.7	
Genuer	Male	246	33.3	
	1-3	187	25.3	

Household size	4-6	328	44.4
categorized	7+	223	30.2
	Owned	345	46.7
Is the house	Rented	380	51.5
owned or rent	Rent free	11	1.5
	Other(specify)	2	.3
How many	1-3	565	76.6
rooms are in	4-6	163	22.5
your house	7+	7	0.9
	None	66	8.9
Highest lovel of	Primary	184	24.9
	Secondary	386	52.3
education	Tertiary	84	11.4
	Don't know	18	2.4
	Business	320	43.4
	Civil servant	64	8.7
Occupation of	Informal sector	43	5.8
the participant	Farmer	9	1.2
	Student	60	8.1
	Not working	242	32.8
Poligion of the	Christian	626	84.8
Religion of the	Muslim	103	14.0
panticipants	Ancestority/Traditional religion	9	1.2
Marital atatus of	Married	433	58.7
narticipante	Single	273	37.0
participants	Divorced/widow	32	4.3

N=Total number of participants; n=number of participants per category; %=percentage

Knowledge of Participants on WASH and Diarrhea Prevention

Over two-thirds of participants did know that diarrhea can be prevented by drinking potable water (72.2%), defecating in a toilet (84.6%) and by cooking food hygienically (70.1%). However, more than three-quarters of them were aware of hand washing as a method of diarrhea prevention (76.4%) though only 67.8% reported using soap to wash hands (Table 3). Overall, only 38.3% of participants had good knowledge (had a mean knowledge score of \geq 50%) on WASH in diarrhea prevention (Fig. 1). Analyzing the socio-demographic factors independently associated with good knowledge revealed health district of residence that was significantly associated with good knowledge. Respondents from Bepanda (Deido Health district) and New Bell were 7.16 and 3.89 times, respectively more likely to have good knowledge on WASH compared to those from Nylon. Household size was associated with good knowledge though this was not significant (Table 4).

	Health District						
Parameter	Response	e Deido n	(%) Nev	v Bell n (%)	Nylon r	ı (%)	Total
n(%)							
Can diarrhea be prevented	Yes	52 (26.5)	04 (28.7	7) 49	(27)	205 (27.8)
by drinking treated water?	No	144(73.5)	258 (71	.3) 131	(73)	533 (72.2)
Diarrhea can be prevented b	y Ye	es 28	(14.3)	64 (17.7)	22(12	2)	
114 (15.4)							
defecating in the toilet	No	168(85.7)	298 (82	.3) 15	8 (88)	624	(84.6)
Proper handwashing is a	Yes	144 (73.5)	287 (7	9.3) 13	3(73.9)	564	(76.4)
method to prevent diarrhea	No	52 (26.5)	75 (20.7	7) 47	' (26.1)	174	(23.6)
Diarrhea can be prevented b (67.8)	y Ye	es 12	7 (64.8)	253 (69.9)	120 ((66.7)	500
using soap to wash hands 238 (32.3)	Ν	o 69	9 (35.2)	109 (30.1)	60 (3	33.3)	
Cooking food hygienically is	Yes	73 (37)	100 (2	(7.6) 4	8 (26.7)	221	(29.9)
important in preventing diarr	hea No	123 (63)	262 (7	72.4) 13	32 (73.3)	517	(70.1)

Table 3: Knowledge of Participants on WASH and Diarrhea Prevention



Fig. 1: Level of knowledge of participants of WASH and diarrhea prevention

				95% CI	
Variable	Categories	AOR	Sig.	Lower	Upper
	Bepanda (Deido HD)	7.16	0.000	4.3	11.8
	New Bell	3.89	0.000	2.4	6.2
Health district	Nylon	1			
	Female	0.86	0.357	0.61	1.19
Gender	Male	1			
	> 10	1.68	0.141	0.84	3.34
	1_3	1.52	0.072	0.96	2.40
	4_6	1.30	0.212	0.86	1.95
Household size	7_10	1			
	Christian	0.36	0.171	0.08	1.56
	Muslim	0.27	0.096	0.06	1.26
Religion	Traditional	1			

Table 4: Factors Independently Associated with Good Knowledge

HD: Health District; AOR: Adjusted Odds Ration; CI: Confidence interval; sig: significance

Attitude of Participants on WASH

Most of respondents (80.9%) considered their drinking water as safe. Those who regarded their drinking water as unsafe complained of its taste or smell (48.9%), microbial pollution (27%), the fact that it made them ill (24.1%) and also, its colour (6%). Littering the environment with rubbish was considered a big problem in the study area by the majority of participants (72.1%) with most of these being respondents from New Bell (77.6%). This causes blockage of the drainage system, which results in flooding after heavy rains and consequently, contamination of water sources, resulting in outbreaks of diarrhea disease. Over three-quarters of respondents (76.6%) considered littering the environment with rubbish as a crime (Table 5). Overall, 66% of respondents had a good attitude on WASH (Fig. 2).

Table 5: Attitude of Participants on WASH

		Health District				
Parameter	Response	Deido No	ew Bell	Nylon	Total	
		n (%)	n(%) n(%)	n (%)	
How do you consider	A big problem	36 (69.4)	268 (74.0)	130 (72.0)	534 (72.4)	
water shortage?	Not a problem	60 (30.6)	94 (26.0)	50 (28.0)	204 (27.6)	
Do you think your	Yes	146 (74.5)	304 (84.0)	147 (82.0)	597 (80.9)	
water is safe drinking	? No	50 (25.5)	58 (16.0)	33 (18.0)	137 (18.6)	
If No, why?	It's appearance	45 (90)	46 (85.2)	29 (87.9)	120 (87.6)	
	Bugs/worms/bacte	ria 18(36)	14 (25.9)	5(15.2)	37 (27)	
	Chemical/pesticide	11 (22.0)	8 (14.8)	6 (18.2)	25 (18.2)	
	Too much chlorine	13 (26)	8 (14.8)	2 (6.1)	23 (16.8)	

	Tastes or smells bad	21 (42)	27 (50)	19 (57.6)	67 (48.9)
	Makes me ill	12 (24)	14 (25.9)	7 (21.2)	33 (24.1)
How do you consider	A big problem	124 (63.3)	281 (77.6)	126 (70)	532 (72.1)
your environment	Not a problem	72 (36.7)	81 (22.4)	54 (30)	206 (27.9)
littered with rubbish?					
Do you consider	Yes	112 (18.6)	263 (43.7) 86 (14.3)	461 (76.6)
polluting the	No	35 (5.8)	46 (7.6)	60 (10)	141 (23.4)
environment a crime?					

n=number of participants per category; %=percentage



Fig. 2: Attitude of respondents to WASH

Being a student (AOR= 0.53, CI 0.30-0.93, p=0.026) or civil servant (AOR=0.56, CI0.32-0.96, p=0.036) was 0.53 times, and 0.56 times respectively less likely to have good attitude to WASH and this was statistically significant (Table 6).

Table 6: Factors Indepen	dently Associated	with Good Attitude
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Variable				95% CI	
variable	Categories	Sig.	AOR	Lower	Upper
Household size	7_10	0.421	0.74	0.36	1.54
	4_6	0.167	0.61	0.31	1.23
	1_3	0.105	0.55	0.27	1.13
	>10		1		
Occupation	Unemployed	0.747	0.94	0.66	1.35

Students Farmer	0.026 0.524	0.53 1.68	0.30 0.34	0.93 8 26
Informal sector	0.495	1.29	0.62	2.67
Business		1		

AOR: Adjusted Odds Ration; CI: Confidence interval; sig: significance

Participants' Practices on WASH

The majority of participants obtained drinking water from a public tap (42%). Other major sources of water reported were rainwater (37%), well water (32%), tap inside the house (29.1%) and private tap in yard (25.6%) (Table 7). Overall, 97% of participants took less than 30 minutes to get water and return home, with the majority (41.1%) taking 5-10 minutes. Only 23% of participants sometimes did not have access to tap water for 24 hours. However, only 38.3% treated drinking water at home, mainly by filtration (89%). Most respondents stored drinking water in a container (90.4%) with 98.1% ensuring that container was closed.

Proper hand washing was a common practice in study communities as 99.1% of respondents reported washing their hands with soap though regular hand washing was practiced by 77% of respondents. With regards to critical periods for hand washing, all participants (100%) washed hands before eating, 78.6% washed hands after using the toilet, 65.7% washed hands before handling food while only 34.2% washed hands after changing diapers. Hand washing facilities were found in 33.1% of homes of which only 32.7% had soap (Table 7). Refuse was disposed mainly into vats (86.7%) which were subsequently emptied by the waste disposal company. However, a few respondents disposed refuse in a river (4.1%) or burnt it (3.3%). The environment of 72.1% of the houses was clean as it was not littered with refuse (Table 7).

With regards to sanitation practices, respondents used mainly pit latrine (59.3%) to dispose human waste. Half of them (50.5%) shared these facilities. Feces was observed in the environment of 7.9% of houses, though only 0.8% reported open defecation. 68.4% reported cleaning the toilet daily, while 30.2% cleaned after one week (Table 7). Overall, 80% of participants had good practices on WASH (Fig.3).

	Health District					
	Deido n(%)	New Bell n(%)	Nylon n(%)	Total n (%)		
What are the sources of water for drinking and domestic use						
Tap inside house	62 (31.6)	99 (27.3)	54 (30)	215 (29.1)		
Private tap in the yard	61 (31.1)	94 (26)	34 (19)	189 (25.6)		
Public or shared standpipe	76 (39)	151(41.7)	83 (46.1)	310 (42)		

Table 7: Participants' Practices on WASH

Neighbor's tap	20 (10.2)	57 (15.7)	29 (16.1)	106 (14.4)
Purchased bottled water	30 (15.3)	58 (16)	34 (19)	122 (16.5)
Rainwater collection	60 (30.6)	139(38.4)	74 (41.1)	273 (37)
Boreholes	10 (5.1)	10 (3)	12 (7)	32 (4.3)
Well water collection	56 (28.6)	113(31.2)	67 (37.2)	236 (32)
How long does it take for you to fetch water				
and back home?				
< 5 minutes	108(14.6)	198(26.8)	108(14.6)	241 (32.7)
5-10 minutes	36 (4.9)	56 (7.6)	38 (5.1)	303 (41.1)
10-30 minutes	48 (6.5)	92 (12.5)	32 (4.3)	172 (23.3)
> 30 minutes	4 (0.5)	16 (2.2)	2 (0.3)	22 (3)
Do you have access to tap water for all 24				
hours of the day?				
Yes	159(81.1)	269 (76)	134(74.4)	562 (77)
No	37 (18.9)	85 (24)	46 (25. 6)	168 (23)
Do you normally treat your drinking water at				
home?				
Yes	195(99.5)	87 (24.0)	1 (0.6)	283 (38.3)
No	1 (0.5)	275(76.0)	179(99.4)	455 (61.7)
If yes, how do you normally treat it?				
Boil	45 (23.1)	20 (23.0)	0 (0.0)	65 (23.0)
Filter	169 (87)	82 (94.3)	1 (100)	252 (89.0)
Add chlorine	53 (27.2)	20 (23.0)	0 (0.0)	73 (25.8)
Do you normally keep drinking water in a				
drinking water container?				
Yes	180(91.8)	322 (89)	165(91.7)	667 (90.4)
No	16 (8.2)	40 (11)	15 (8.3)	71 (9.6)
If yes, in what sort of container do you store				
your drinking water	470(00.4)		400 (07)	054 (00.4)
	179(99.4)	314(97.5)	160 (97)	654 (98.1)
Opened container	1 (0.6)	8 (2.5)	5 (3)	13 (1.9)
Voc	106 (100)	250(00 0)	177(00.2)	721 (00 1)
res No	196 (100)	308(98.9)	1//(98.3) 2 (1 7)	731 (99.1)
NO	0 (0.0)	4 (1.1)	5(1.7)	7 (0.9)
If Yes, how often do you wash your hands?				
Always	148(75.5)	281(78.5)	134(75.7)	563(77)
Sometimes	48(24.5)	77(21.5)	43(24.3)	168(23)
When do you wash your hands?	. ,	. ,	. ,	. ,
Before eating	196(26.6)	362(49.1)	180(24.4)	738 (100)
After using the toilet	163(22.1)	276(37.4)	141(19.1)	580 (78.6)
Before handling food	119(16.2)	242(32.8)	123(16.7)	484 (65.7)
				-
After using the toilet Before handling food	163(22.1) 119(16.2)	276(37.4) 242(32.8)	141(19.1) 123(16.7)	580 (78.6) 484 (65.7)

Hand washing facilities present				
Yes	84(11.4)	136(18.4)	24 (3.3)	244 (33.1)
No	112	226	156	494 (66.9)
	(15.2)	(30.6)	(21.1)	
Soap available				
Yes	79 (10.7)	141(19.1)	21 (2.9)	241 (32.7)
No	117(15.9)	221 (30)	159(21.5)	497 (67.3)
How do you dispose your domestic waste?				
Into a vat and then Collected by disposal	172(87.6)	289(79.8)	149(82.8)	640(86.7)
company				
Burn	6(3.1)	13 (3.6)	5 (2.8)	24 (3.3)
Bury	0 (0)	0 (0)	2 (0.3)	2 (0.3)
Dispose in a river	6 (3.1)	16 (4.4)	8 (4.4)	30 (4.1)
Household environment clean				
Yes	146(19.8)	236 (32)	150(20.3)	532 (72.1)
No	50 (6.8)	126(17.1)	30 (4.1)	206 (27.9)
How do you dispose of human waste?				
Flush Toilet	79(40.3)	114(31.5)	85(47.2)	78(37.7)
Pit Latrine	112(57.1)	235(64.9)	91(50.6)	438(59.3)
Both	5(2.6)	9(2.5)	2(1.1)	16(2.2)
Open defecation	0(0)	4(1.1)	2(1.1)	6(0.8)
Human or animal feces around the house				
Yes	18 (2.4)	35 (4.7)	5 (0.7)	58 (7.9)
No	178 (24)	327(44.3)	175(23.7)	680 (92.1)
Do you share your toilet/latrine with				
neighbour?				
Yes	96(49)	201(55.5)	76(42.2)	73(50.5)
No	100(51.0)	161(44.5)	104(57.8)	365(49.5)
How often do you clean and disinfect your				
latrines/toilet?				
Daily	143(73)	240(66.3)	122(67.8)	505(68.4)
After one week	52(26.5)	117(32.3)	54(30)	223(30.2)
When it is dirty	1(0.5)	5(1.4)	4(2.2)	10(1.4)

n=number of participants per category; %=percentage



Fig: Level of Practices of participants on WASH

With regards to factors associated to good WASH practices, participants residing in New Bell (p=0.027, AOR=0.57, 95% CI: 0.35-0.94) were 0.57 times significantly less like to have good practices compared to those from Nylon. Those house owners were 2.17 times significantly more likely to have good practices on WASH (p=0.000, AOR=2.17, 95% CI: 1.42-3.31)(Table 8).

				95% CI	
Variable	Categories	Sig.	AOR	Lower	Upper
	Bepanda	0.396	0.78	0.45	1.38
	New Bell	0.027	0.57	0.35	0.94
Community	Nylon		1		
	> 10	0.094	0.52	0.24	1.12
	1_3	0.288	1.37	0.76	2.47
	4_6	0.793	0.94	0.57	1.53
Household size	7_10		1		
	Yes	0.000	2.17	1.42	3.31
House owner	No		1		
	Christian	0.287	2.20	0.52	9.42
	Muslim	0.204	2.68	0.59	12.27
Religion	Others		1		
	Married	0.118	2.02	0.84	4.87
	Single	0.264	1.65	0.68	4.01
Marital status	Divorce/widow	-	1		

Table 8: Factors Independently	Associated with Good Practice
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AOR: Adjusted Odds Ratio; CI: Confidence interval; sig: significance

Prevalence of Diarrhea based on Household Survey

Diarrhea was reported by 129 of respondents giving a prevalence of 17.5%. The highest prevalence (34.1%, 44) was in children 1 to 5 years, followed by those < I year old (14.7%, 19). The difference with respect to age group was significant (χ^2 = 738, P= 0.00). Diarrhea prevalence was highest (23.3%, 52) in household with more than 7 persons (23.3%) and lowest in households with 1-3 persons (11.8%). The difference was significant (χ^2 =9.620, p=0.008). The highest prevalence of diarrhea (19.2%, 74) was observed in participants with secondary education and the lowest (10.7%, 9) among those with tertiary education. Participants from New Bell District reported highest prevalence (22.4%, 81). There was no significant difference in diarrhea prevalence based on level of education (P>0.05), but the difference with respect to health district (χ^2 = 14.487, p=0.001), household size (χ^2 = 9.620,p=0.008) and age (χ^2 = 73.8, p=0.000) was significant.

		Diarrhea?		
Predictor	Categories	Yes	v2-test	
		n/N (%)		
	Less than 1 year	19/129 (14.7)		
	1-5 years	44/129 (34.1)		
	6-10 years	9/129 (7.0)		
	11-15 years	7/129 (5.4)		
	16-20 years	7/129 (5.4)		
	21-25 years	12/129 (9.4)	χ2=738.000	
Age groups	26-30 years	10/129 (7.6)	P=0.000	
	31-35 years	3/129 (2.3)		
	36-40 years	1/129 (0.9)		
	41-45 years	5/129 (3.9)		
	46-50 years	3/129 (2.3)		
	>50 years	9/129 (7.0)		
Household size	1-3	22/187 (11.8)	v2-0.620	
	4-6	55/328 (16.8)	AZ-9.020 D=0.008	
categorizes	7+	52/223 (23.3)	r -0.000	
	None and primary	46/268 (17.2)	$y_{2} = 3.440$	
The level of education	Secondary	74/386 (19.2)	$\chi^2 = 0.449$ P = 0.178	
	Tertiary	9/84 (10.7)	1 - 0.170	
	Deido	19/196 (9.7)	$-\sqrt{2} = 14.487$	
Health Districts	New Bell	81/362 (22.4)	_ P= 0 001	
	Nylon	29/180 (16.1)	i — 0.00 i	

Table 9: Prevalence of Diarrhea in Study Communities

N=Total number of participants; n=number of participants per category; %=percentage

Association between Knowledge, Attitude and Practices of WASH and Occurrence of Diarrhea in the Community

Multiple regression analysis of the association between participants' level of KAP with the occurrence of diarrhea indicates that the odds of participants with good attitude developing diarrhea was 0.6 times significantly less than those with poor attitudes (p=0.011, AOR=0.600, 95% CI: 0.404-0.891). Participants with good knowledge (p=0.066, AOR=0.682, 9% CI: 0.454-1.025) and good practices (p=0.084, AOR=0.666, 95% CI:0.420-1.056) were less likely to have diarrhea compared to those with poor knowledge and poor practices but the associations were not significant (Table 10).

Table 11: Association between Knowledge, Practice, Attitude of WASH and Diarrhoea Occurrence

Variable	Categories	Sig.		AOR			95% C	<u>) </u>
	-	-				Lower	٢	Upper
Knowledge	Good	0.066		0.682		0.454		1.025
·	Poor			1				
Attitude	Good	0.011		0.600		0.404		0.891
	Poor		_					
1								
Practice	Good		0.084		0.666		0.420	
1.056								
	Poor		_					
1								

AOR: Adjusted Odds Ratio; CI: Confidence Interval; Sig: Significance

Prevalence of Diarrhea based on the Retrospective Study

Overall, the prevalence of diarrhea based on the retrospective study was 11.1%. The prevalence was significantly higher in male (13.0%) than in female (χ 2=23.889, p=0.000) (Table 12), and highest in CMA Nkololoun in New Bell health district (13.5%) (χ 2 = 57.617, p=0.000). With regards to age, the prevalence was highest in children < 1 year old (23.1%) followed by those 1-5 years old (16.1%) (χ ²⁼ 95.710, p=0.000). More cases were recorded in 2011 (14.1%) (χ 2=23.432, p=0.000).

Table 12: Prevalence of Diarrhea based on the Retrospective Study

Predictor	Catagorias	Diarrhea?	Chi-square test)	(χ2-
	Categories	Yes n/N (%)	P-values	
Gender of	Male		χ2=23.889	

the patient		436/3326 (13.0)	P=0.000
are periorit	Female	438/4558 (9.6%)	
	Total	874/7884 (11.1%)	_
	CMA Nkololoun (New Bell)	312/2315 (13.5%)	0.57.047
Health	CMA Bepanda (Deido)	328/2532 (13.0%)	- χ2=57.617
facility	Despansaire Catholique Barcelone (Nylon)	234/3037 (7.7%)	- P=0.000
	Business	98/974 (10.1%)	
	Civil Servant	11/143 (7.7%)	_
	Informal sector	78/862 (9.0%)	_
Occuration	Student	166/1626 (10.2%)	_
Occupation	Retired	22/212 (10.4%)	 χ2=100.141
or the	Child	201/1042 (19.3%)	P=0.000
patients	Housewife	122/1540 (7.9%)	_
	Pupils	145/1137 (12.8%)	_
	None	29/336 (8.6%)	_
	Farmer	2/12 (16.7%)	_
	<1	34/147 (23.1%)	
	1-5	235/1463 (16.1%)	_
	6-10	100/672 (14.9%)	_
	11-15	49/474 (10.3%)	_
	16-20	50/628 (8.0%)	_
Age	21-25	85/914 (9.3%)	χ2=95.710
Categorized	26-30	76/852 (8.9%)	P=0.000
	31-35	54/558 (9.7%)	
	36-40	39/397 (9.8%)	
	41-45	29/302 (9.6%)	
	46-50	20/262 (7.6%)	
	50+	103/1215 (8.5%)	
	2011	166/1175 (14.1%)	
-	2012	178/1387 (12.8%)	- v2=23 432
Year	2013	208/2051 (10.1%)	AZ=20.402
	2014	167/1793 (9.3%)	1 -0.000
	2015	155/1478 (10.5%)	_

Research Implications/Limitations

This was a cross-sectional community-based study that investigated the prevalence of diarrhea disease and evaluated the KAP of participants on WASH, and their association to diarrhea in three cholera endemic localities: Deido, New Bell and Nylon in Douala, Cameroon. In addition, a retrospective hospital-based study was also conducted to understand the trend of occurrence of diarrhea in these localities over a period of five years, from 2011 to 2015. The prevalence of

reported diarrhea in the community was 17.5% as against 11.1% in the retrospective study. This shows that more cases of diarrhea were managed in the community than in health facilities. The study site has witnessed several outbreaks of cholera. During these outbreaks, community members were educated on first aid management of mild cases. The higher prevalence of diarrhea in the community than in the retrospective study could be that they were mild and could be managed at home, while severe cases sought medical care. Also, some patients might have presented in other health facilities not included in our study resulting in an underestimation of diarrhea in the hospital- based study. The highest prevalence of diarrhea was observed in 2011. This coincided with the period when there was an outbreak of cholera in Douala and other parts of Cameroon (UNOCHA, 2015). There was a general decline from 2011 to 2015. The prevalence of diarrhea in the community-based study is similar to 17.6% reported in children in Ethiopia (Getahun et al., 2021), but higher than 10.77% reported in the general population in Southeastern Nigeria (Ugochukwu et al., 2020). This study focused on cholera endemic localities where there is a likelihood of a high prevalence of other diarrhea diseases. In addition, participants reported diarrhea within a period of one month while in the study of Ugochukwu et al. (2020) diarrhea reported was two weeks prior to the study, explaining the large difference. The prevalence of diarrhea was significantly highest in household with more than 7 persons (23.3%) compared to those with a household size of 1-3 person (11.8%), highlighting the contribution of overcrowding in diarrhea spread. Children <5 years had the highest prevalence of diarrhea in both the community-based study and the retrospective study, confirming reports on the high vulnerability of this age group to diarrhea (Manetau et al., 2021; UNICEF, 2021). Recurrent diarrhea in children affects growth, cognitive development and also causes malnutrition (Pickering et al., 2015; Cumming and Cairncross, 2016). Thus, there is a need to fight against diarrhea in the study community.

With regards to participants' knowledge on WASH and diarrhea prevention, participants were more knowledgeable on hand hygiene and diarrhea prevention as the majority of them knew diarrhea can be prevented by proper hand washing. They were not knowledgeable on diarrhea prevention by drinking treated water (72.2%), defecating in the toilet (84.6%) and cooking food hygienically (70.1%). This reflects their practices, as only 38.3% treated drinking water and 0.8% practiced open defecation though feces were observed around the houses of 7.9% of respondents showing that respondents were not sincere on their response to open defecation.

The high level of awareness of hand hygiene in diarrhea disease prevention could be due to the numerous sensitization campaigns during cholera outbreaks. Overall, only 38% of participants had good knowledge on WASH (Fig. 1). This is lower than 42.2% with good knowledge on WASH in Tigray region, Ethiopia (Berhe et al., 2020). The overall low level of knowledge on diarrhea prevention in our study is surprising because during cholera outbreaks in these localities, interventions have been conducted to educate inhabitants on prevention measures. Our findings underscore the need for frequent sensitization campaigns on diarrhea prevention in study sites. Of the factors analyzed for association with good knowledge, only health district of residence had a significant association, as the odds of having good knowledge among participants from Bepanda (Deido health district) and New Bell were 7.16 times (p=0.000, AOR=7.16, 95% CI: 4.3-11.8) and 3.89 times (p=0.00, AOR= 3.89, 95% CI: 2.4-6.2), respectively more likely to have good

knowledge compared to those from Nylon (Table 6). Participants with good knowledge were 0.682 times less likely to have diarrhea compared to those with poor knowledge though this association was not significant (p= 0.066, AOR=0.682, 95% CI: 0.454-1.025).

With regards to attitude on WASH, the majority of participants considered water shortage a problem, regarded their drinking water as safe, considered littering of the environment as a problem and a crime. Arbitrary refuse dumping causes the blocking of the drainage system and this results in flooding, particularly after heavy rainfall. Flooding contaminates water sources and causes diarrhea diseases. Among those who perceived the quality of water as unsafe, over three-quarters mentioned its appearance while almost half (48.9%) complained of its taste or smell. Good attitude on WASH was observed in about two-thirds (66%) of study participants. This is higher than 48.5% reported in northern Ethiopia (Berhe et al., 2020), but less than 73.6% in Northwest Ethiopia (Abera et al., 2018). The odds of having a student (p=0.026, AOR=0.53, 95% CI:0.30-0.93) and civil servant (p=0.036, AOR=0.56, 95% CI: 0.32-0.96) having good attitude was 0.53 times and 0.56 times, respectively significantly less than in business men. Participants with good attitude (p=0.011, AOR=0.600, 95% CI: 0.404-0.891) were 0.600 times less likely to have diarrhea compared to those with poor attitude and the difference was significant. This is because poor attitude may influence practices, increasing the risk of infection.

Concerning the practices of participants on WASH, the majority of participants obtained drinking water from improved sources, while up to 32% obtained drinking water from wells. Previous reports from our study site (Akoachere et al., 2013a; 2013b) showed that the water quality of most wells is poor. In addition, toxigenic V. cholerae was isolated from some wells (Akoachere et al., 2014). Thus, participants obtaining drinking water from wells are at risk of cholera and other diarrhea diseases particularly as treatment of drinking water was practiced by few of them (38.3%). Treatment of drinking water was mainly by filtration (89%) among those who reported treating water, similar to the report of Berhe et al. (2020). This is a low-cost, convenient method of water treatment. However, we did not find out from participants whether they changed the filter as required to ensure its efficiency. Only 29.1% had tap inside the house. Most participants obtained water from public standpipes and from taps in the yard. Such a practice increases the risk of contamination when the water is transported home. Notwithstanding, our findings showed that participants had good access to water as the majority of them took less than 10 minutes to obtain water and back. To ensure availability of water during periods when the tap was not running, participants stored water (90.4%) in closed containers (98.1%). This is a good practice as it ensures hygiene and prevents contamination.

Almost all participants (99.1%) reported washing hands with soap, though regular hand washing was practiced by only 77% participants. Regular hand washing using soap is a good practice, which must be encouraged as this is important not only in the prevention of diarrhea but also several infectious diseases. Hand washing facilities were found in only 33.1% of homes and of these, soap was found in only 32.7%. This is lower than the national rate of 36% of households with hand washing facilities with soap (UN, 2020). Based on this observation, respondents might not have been sincere in some of their responses to hand hygiene practices. Notwithstanding,

participants were aware of the critical times to wash hands except hand washing after changing diapers (34.2%).

Participants had good basic sanitation practices. 86.7% disposed refuse in vats which are subsequently emptied by the waste disposal company. This prevents littering of the environment which may block drainage ditches resulting in flooding and may also serve as breeding sites for mosquitos. Participants used mainly pit latrines for human waste disposal. This is because it is cheap and only 0.8% of respondents reported open defecation, though feces was observed in the surroundings of 7.9% of homes, which is evident of open defecation. This is higher than the national open defecation rate of 6% (UN, 2020). To prevent contamination of food and water, the practice of open defecation should be discouraged. Sharing of toilet with other households was reported by half of the respondents. Ugochokwu et al. (2020) reported sharing of toilet facilities as a risk factor for diarrhea disease. This is because when these facilities are shared, users never ensure proper hygiene. Most participants (68.4%) reported cleaning the toilets daily. Overall, good practices on WASH were observed in 80% of respondents. This is higher than 48.5% reported among rural residents in Ethiopia (Berhe et al., 2020). This indicates a higher quality and coverage of community health services in this study area. In this study, the odds of having good practices in WASH were 0.57 times significantly less in New Bell than in Nylon (p=0.027, AOR=0.57, 95% CI, 0.35-0.94). This association was significant and may confirm the significantly high prevalence of diarrhea in New Bell observed in the community-based study and in the hospital-based study. This was further confirmed in the multivariate analysis which revealed that participants with good practices were 0.666 times less likely to have diarrhea compared to those with poor practices (p=0.084, AOR=0.666, 95% CI:= 0.420-1.056) though the association was not significant.

The limitations of this study were reporting bias that would have resulted in participants providing answers that did not represent their real practices and recall bias for some variables. The retrospective study involved only one all health care facility of the numerous health care facilities in each health district, thus the reported diarrhea prevalence might be an underestimation. This study was a quantitative study and issues that can be addressed through qualitative study to better understand WASH in study area were not addressed.

The study has revealed a high diarrhea prevalence in study areas and also shows that overall, only 38% of participants had good knowledge of diarrhea prevention. Participants with good attitude towards WASH were significantly less likely to have diarrhea while those with good knowledge and good practices were less likely to have diarrhea though the association was not significant. This study has also identified gaps in WASH that need to be addressed to prevent the occurrence of diarrhea disease and suggest frequent WASH education to improve respondents' knowledge of diarrhea disease prevention and promote good attitude and practices towards WASH.

Originality/Value of Paper

Findings of this study may contribute to efforts to monitor Cameroon's progress towards the achievement of the UN Sustainable Development Goals, particularly SDG #6: Clean Water and Sanitation, Goal #3: Health and Well-being and also Goal #11: Creating Inclusive and Sustainable Cities. Our findings show that there is an urgent need for interventions on WASH in the study areas; continuous health education on the prevention and control of water borne diseases to further enhance a change in behavior and reduce the occurrence of gastrointestinal diseases. The research team intends to collaborate with the Douala Municipality and public health authorities to ensure improvement in WASH and behavioral change of inhabitants of study localities.

Acknowledgements

We are thankful to the University of Buea for funding our participation at the WIM Conference. We are grateful to Professors Roland N. Ndip, Mvondo Awono Jean Pierre, Egbe Andrew, Asongalem Emmanuel Acha and Aaron Tening, for their valuable suggestions and Professor Samuel N. Ayonghe for coordinating University of Buea's preparations for the WIM conference. We acknowledge Professor Nicolas Tendongfor for his assistance in data analysis and Drs. Roy Lyonga Mbua And Engome Regina Wotany for their input.

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STARS-c, A Google Earth Engine Tool to Evaluate Long-Term Water Quality Trends Globally

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Abstract

We present the SpatioTemporal Analysis of Remotely Sensed chl-*a* tool (STARS-c) tool, based on Google Earth Engine (GEE) and Landsat data. STARS-c characterizes water quality trends for any water body globally. STARS-c allows a user to outline a water body, select a time range, and apply a general or user-provided model to estimate chlorophyl-a (chl-*a*) concentrations. STARS-c generates maps of chl-*a* concentrations and provides chl-*a* concentrations over time. Historically, remote sensing data use required significant computational resources because of the data size. STARS-c leverages GEE which performs computations remotely and requires only a web browser. STARS-c can help manage water resources in a sustainable manner.

This paper primarily addresses UN Sustainability Goal 6: Clean Water and Sanitation, and Goals 11, 13, and 14: Sustainable Cities and Communities, Responsible Consumption and Production, Climate Action, and Life Below Water, respectively. STARS-c provides a long-term time history of water quality, including spatially distributed concentration maps which can be used to better manage water resources and waste water treatment (G6), provide input to help design and plan sustainable cities by identifying impacted water bodies and trends (G11), help locate water and waste water treatment plants and evaluate waste water treatment effectiveness over the last 40 years (G13), provide data on long-term trends to help characterize and evaluate climate impacts and potential mitigation strategies (G13), and identify both sustainable and impacted water bodies to help address issues in life below water (G14).

Key words: chlorophyl concentration, water quality trends, remote sensing

Purpose

Eutrophication of Freshwater Systems

Eutrophication of surface waterbodies, which is defined as the excessive growth of algae and other organisms due to high nutrient levels in the water column (Khan and Ansari, 2005), is a prevalent, serious, and growing problem around the world. The effects of eutrophication, which include the growth of cyanotoxin-producing Harmful Algal Blooms (HABs) (Anderson et al., 2002), cause extensive environmental damage (Christoffersen, 1996, Paerl and Otten, 2013) in addition to economic losses in the form of increased drinking water treatment costs, spending on recovery of threatened and endangered species, diminished recreational use, and decreased value of waterfront real estate (Dodds et al., 2009). Eutrophication-related HABs also cause adverse

health effects for humans who are exposed or drink the water containing the toxins (Falconer, 1999, Chorus and Welker, 2021). It is known that human activities contribute to eutrophication of surface waters by influencing the loading of growth-limiting nutrients to aquatic systems (Caraco, 1995) and that increases in human population density and land use alterations are associated with eutrophication of nearby waterbodies (Smith, 2003).

Eutrophication of waterbodies due to human activity is predicted to continue to increase (Bennett et al., 2001, Paerl and Huisman, 2009), so there is great need for tools that will help water managers evaluate strategies for preventing and remediating eutrophication. Some success at preventing and remediating eutrophication has been achieved through methods such as controlling sources of nutrient pollution and conducting biological restoration efforts (Zhang et al., 2020, Stuart, 2001); however, in order to predict the success of these strategies, which are often costly and difficult to implement, water managers must understand the nature and cause of the eutrophication (Carpenter et al., 1999). Examining historical data can provide significant insight into this question, but very few lakes and reservoirs around the world have any kind of historical water sampling data, let alone the comprehensive dataset that would be required to effectively analyze spatial and temporal trends in water quality.

Water Quality Analysis using Remotely-sensed Data

Using remotely-sensed data addresses the lack of historical and spatially comprehensive water sampling data—researchers have successfully used satellite data to examine water quality since the early 1970's (Strong, 1974, Klemas, 2012, Richardson, 1996, Stumpf, 2001). The NASA Landsat satellite series, which has been generating useful data since 1984, collect multispectral images which can be used to evaluate plant growth, water quality, and other parameters (Brezonik et al., 2005, Hansen et al., 2015, Strong, 1974). Landsat images can be used to calculate estimates of chlorophyll-a (chl-a), a plant pigment often used as an index for algal biomass (Shi et al., 2019). Despite the ecological differences in freshwater systems around the world, they respond in similar ways to excess nutrient availability in the water column-specifically, with a marked increase in algal biomass and similar changes in species composition (Smith, 2003). Because of this, measuring changes in algal biomass (using chl-a as an index) is an effective method of studying trends in eutrophication for lakes and reservoirs anywhere in the world. Until recently, such analyses using remotely-sensed data were difficult and time consuming due to the large amount of data and the processing required to get the data in a usable form. The release of the Google Earth Engine (GEE) platform greatly simplified the work of retrieving, processing, and analyzing remotely sensed data, and makes it possible to analyze satellite data with just a web browser (Hansen, 2015).

STARS-c: A Tool for Analyzing Algal Blooms with Landsat Data

Building off of prior research using GEE to conduct analyses of algal bloom trends with Landsat data (Hansen et al., 2013) (Hansen et al., 2015) (Tate, 2019) (Cardall et al., 2021), we developed the SpatioTemporal Analysis of Remotely Sensed chl-*a* tool (STARS-c) to further simplify the process of conducting a remote sensing study and make it possible for anyone with an internet

connection to outline any water body, select a time range, and use either a general or userprovided model to estimate chl-*a* concentrations for that water body from 1984 to the present. STARS-c can generate stand-alone maps of chl-*a* concentrations for selected dates and provide data on long-term time series of chl-*a* concentrations. It excludes "low quality" pixels, such as pixels with clouds or dry land, from the analysis. Data generated with STARS-c characterize the spatial and temporal patterns in algal biomass of the selected water body and help water managers evaluate the success of current and proposed strategies for preventing and mitigating eutrophication by helping to identify nutrient sources, regions most impacted by nutrient inflows, and other conditions affecting the water body.

Methods

Google Colabatory and Earth Engine

Colabatory Google Google (Colab) is а service provided bv Research (https://colab.research.google.com/). It allows developers and users to write and use python code in a web browser. Colab requires no configuration of the user's computers, provides access to GPUs free of charge, and allows easy sharing of any developed code. Colab uses a "notebook" concept that includes both code and text cells to provide additional context for the code. GEE is integrated into Colab and, for most GEE computational requirements, the data and the code execute on Google servers and GPU units. This is important because of the large size and intensive computation needs of remoting sensing data. For long-term analysis, such as that provided by STARS-c, datasets cover over 40 years and can use anywhere between 100s of gigabytes to more than a terabyte of data. This processing occurs on GEE servers, accessed using Colab notebook. GEE resources can be accessed with python code outside of a Colab notebook, but the notebook framework provides a browser-based tool that can be used by water managers and researchers with limited access to advanced computer resources.

STARS-c requires several python libraries. When a Colab notebook such as STARS-c is opened, it creates a new virtual environment on the Google servers. We install the required libraries on this environment in the first few cells of the notebook.

To access GEE computational resources and data, a STARS-c user must have a Google Earth Engine account, and before STARS-c can be run, the notebook the user must authorize the notebook for their account. A notebook cell starts the authorization process, then provides a link for the STARS-c user to authorize the notebook to use their GEE account. Once the required libraries are downloaded and the account authorized, STARS-c is ready for use.

Selecting a Water Body

The first tasks in STARS-c requires the user to select a waterbody for analysis. STARS-c displays a global map where the user can zoom to a waterbody. The user then uses the drawing tools (shown on the left side of **Figure 1** to draw a rectangle or other polygon around the waterbody.

This area will be used for all the subsequent analysis. The analysis will include any waterbodies included in the outline.

Error! Reference source not found. shows an example where a user has selected Lake Taihu, in China, using a rectangular area. As shown by the map, this rectangle includes several small water bodies in the areas near Taihu Lake, these will be included in subsequent analysis. A user can draw a closed polygon to select a more detailed area of interest. In this way, the user can exclude surrounding wetlands from analysis or select a smaller area of the lake to analyze separately from the lake as a whole.

After a user has created the geometry to select a waterbody, the notebook cell after the map (**Figure 1**) creates a variable that contains this geometry to define the area for all subsequent processing. If a user wants to analyze a different area or refine the geometry, they should re-run the cell that generates the map, re-draw the polygon, then run the cell that obtains the geometry.



waterBody = ee.Geometry(Map.user_roi)

Figure 14. A cell showing the cell that displays a map, the cell displaying the map, the geometry created to select a water body, and the subsequent notebook cell that loads this geometry into a variable to define the processing area.

Satellite Data

STARS-c uses Level-2, Collection 2, Tier 1 data from Landsat satellites 5, 7, 8, and 9. The user may modify the code to use different satellite data, but it is recommended to use this data. The Landsat satellites, designed to monitor ecological conditions on the earth's surface, have a 16day return period, 30-meter spatial resolution, a combined range of 38 years (1984-present), and spectral bands specifically designed for vegetation studies, making them ideal for developing detailed time histories of algal concentrations in waterbodies (Brezonik et al., 2005) (Masek et al., 2006) (USGS, 2016). Landsat Level-2 data include surface reflectance images, which are corrected for various sensor and atmospheric effects to best represent the spectral data that are reflected from the earth surface (https://www.usgs.gov/landsat-missions/landsat-collection-2level-2-science-products). Level-2 data also contains pixel quality information and surface temperature data. STARS-c does not currently use surface temperature data, but we hope to include surface temperature summary statistics as an export in the future. Collection 2 images are the product of a second reprocessing effort of Landsat data and contain numerous advantages over Collection 1 data (https://www.usgs.gov/landsat-missions/landsat-collection-2). For this application, notable improvements include consistent quality assessment bands, improved radiometric calibration, and improved surface reflectance and surface temperature products. Tier 1 images are the highest-quality products from the available data. Landsat Level-2, Collection 2, Tier 1 images are readily available through Google Earth Engine.

STARS-c collects every image that contains the user-specified water body available from the
LandsatLandsatarchive,asshowninFigure 15Error! Reference source not found..

Collects all Tier 1, Lav SR images of the area for each satellite L5 = ee.ImageCollection("LANDSAT/LT05/C02/T1_L2").filterBounds(waterBody) L7 = ee.ImageCollection("LANDSAT/LE07/C02/T1_L2").filterBounds(waterBody) L8 = ee.ImageCollection("LANDSAT/LC08/C02/T1_L2").filterBounds(waterBody) L9 = ee.ImageCollection("LANDSAT/LC09/C02/T1_L2").filterBounds(waterBody)

Figure 15. Collecting each image containing the waterbody into an image collection for each satellite (Landsats 5, 7, 8 and 9).

Data Preparation

STARS-c performs three operations to prepare the data for evaluation of chl-*a* concentration: applying the appropriate scaling factor to the bands, renaming the bands, and combining the resulting image collections into a single collection. **Figure 16** shows the code used to apply the scaling factors specified by the USGS as a function. It also shows the code used by STARS-c to apply or map this function over the different Landsat image collections. The scaling factors used for Collection 1 data are different from Collection 2 data; if the user wishes to use Collection 1 data, they will need to modify the code to apply the correct scaling factors.

```
# function to apply scaling factores
def applyScaleFactors(image):
    opticalBands = image.select('SR_B.').multiply(0.0000275).add(-0.2);
    thermalBands = image.select('ST_B.*').multiply(0.00341802).add(149.0)
    image = image.addBands(opticalBands, None, True).addBands(thermalBands, None, True)
    return image
L5Scaled = L5.map(applyScaleFactors)
L7Scaled = L7.map(applyScaleFactors)
L8Scaled = L8.map(applyScaleFactors)
L9Scaled = L9.map(applyScaleFactors)
```



Renaming the bands is not necessary, but it both simplifies computations and makes the code, especially model expressions, more readable. If the bands were not renamed, we would need different function expressions for each Landsat mission; by renaming the bands, a single expression can be used for all the Landsat missions. **Figure 17** shows the function that renames the bands along with the GEE code the applies (i.e., "maps") the function over each image collection. Landsat 5 and 7 data have different band designations from Landsat 8 and 9, so different functions are used.

```
# function to rename Landsat 5 & 7 bands
def L57_BandRenamer(image):
  oldNames = ['SR_B1','SR_B2','SR_B3','SR_B4','SR_B5','SR_B7','QA_PIXEL','ST_B6']
  newNames = ['Blue','Green','Red','NIR','SWIR1','SWIR2','QA_PIXEL','SurfTempK']
  image = image.select(oldNames).rename(newNames)
 return image
# function to rename Landsat 8 & 9 bands
def L89_BandRenamer(image):
  oldNames = ['SR_B1','SR_B2','SR_B3','SR_B4','SR_B5','SR_B6','SR_B7','QA_PIXEL','ST_B10']
  newNames = ['UltraBlue','Blue','Green', 'Red','NIR','SWIR1','SWIR2','QA_PIXEL','SurfTempK']
  image = image.select(oldNames).rename(newNames)
  return image
L5Renamed = L5Scaled.map(L57 BandRenamer)
L7Renamed = L7Scaled.map(L57_BandRenamer)
L8Renamed = L8Scaled.map(L89_BandRenamer)
L9Renamed = L9Scaled.map(L89_BandRenamer)
```

Figure 17. Renaming the bands STARS-c uses in analysis. A different function is used for Landsats 5 and 7 than Landsats 8 and 9, because they have different band designations.

Merging each satellite collection into a single image collection is also not strictly necessary, but it also simplifies computation. STARS-c data exports include the name of the satellite for each image in case it is needed. The code that merges the collections is shown in **Figure 18**.

```
# Merges the band-renamed collections
# and sorts the new collection by date
renamedCollection = L5Renamed.merge(L7Renamed).merge(L8Renamed).merge(L9Renamed)
renamedCollection = renamedCollection.sort('system:time_start')
```

Figure 18. Code to merge image collections.

Image Processing

Land Masking

STARS-c estimates the chl-*a* for water pixels only. We accomplish this by first trimming the image to the boundaries of the user-drawn polygon for the water body, as shown in **Figure 19**.

Clips image to area polygon
image = image.clip(waterBody)

Figure 19. Trimming the image to the polygon drawn for the water body. All pixels inside this polygon will be evaluated for the presence of water and pixel quality, and chl-*a* concentration will be estiamted for each pixel.

STARS-c then applies a water mask using a user-specified water index. Three water indices to choose from are available in a dropdown menu, as shown in

Figure 20: the Normalized Difference Water Index (NDWI), the Modified Normalized Difference Water Index (MNDWI), Normalized Difference Vegetation Index (NDVI).

waterIndex:	NDWI	
	NDWI	_
Show code	MNDWI NDVI	

Figure 20. Drop-down menu to select a water index. Information about these indices is provided in a markdown cell to assist the user in selecting an index.

The user may also modify the code to specify their own water index of choice. The user must specify a threshold value to distinguish land from water. Users should modify this threshold using the visual feedback STARS-c provides to find a number that accurately represent water areas for the waterbody of interest. The water masks are sensitive to water color, turbidity, and other issues, and each water body generally requires some trial and error to select the correct threshold value. Once these parameters have been specified, STARS-c will construct a water mask, as shown in **Error! Reference source not found.**. Error! Reference source not found. shows the polygon-

trimmed RGB image of Lake Taihu (left), the mask that the code creates for this image (middle), and the resulting land-masked image (right).

```
# Computes water index value of each pixel
# and creates land mask
waterIndex = image.expression(waterIndexExpression,
    {
        'Green': image.select('Green'),
        'Red': image.select('Red'),
        'SWIR1': image.select('SWIR1'),
        'NIR': image.select('SWIR1'),
        'NIR': image.select('NIR')
    })
landMask = waterIndex.gt(waterThreshold)
image = image.updateMask(landMask)
```

Figure 21. Masking pixels that contain land. The code gives each pixel a water index based on the prodived model and masks any pixels that are not withing a specified threshold.



Figure 22. Land masking an image of Lake Taihu. The left panel shows the real-color image, the middle panel shows the land mask (with red indicating expelled land pixels),and the right panel shows the land-masked real-color image.

Quality Masking

STARS-c eliminates pixels containing clouds and cloud shadows from analysis by applying a cloud mask to each image. The cloud mask uses the pixel quality assessment band available in all Level 2 data. Use of this band requires bitwise operation, as shown in

Figure 23. For Collection 2 data, bit 3 of the quality band indicates the presence of a cloud and
bit 4 indicates the presence of a cloud shadow. We use bit 9 to set our "cloud confidence" to high
to
ensure
bad
pixels
are
masked.Figure 24 shows a land-masked RGB image of Taihu Lake (left), the cloud mask that the code
creates for this image (middle), and the resulting quality-masked image (right).

```
# Pixel quality mask
qa = vizImage.select('QA_PIXEL')
# If the cloud bit (3) is set
# and the cloud confidence (9) is high
# or the cloud shadow bit is set (3)
# it's a bad pixel.
cloud = qa.bitwiseAnd(1 << 3).And(qa.bitwiseAnd(1 << 9)).Or(qa.bitwiseAnd(1 << 4))
# Remove edge pixels that don't occur in all bands
mask2 = vizImage.mask().reduce(ee.Reducer.min())
# mask image
image = image.updateMask(cloud.Not()).updateMask(mask2)
```

Figure 23. Masking low-quality pixels, including those with clouds and cloud shadows. The code can be read to say: if bits 3 and 9 are set, i.e., there are clouds and confidence in there being clouds is high, or if bit 4 is set, i.e., there is a cloud shadow, then mask the pixel.



Figure 24. Quality masking an image of Lake Taihu which contains some clouds and cloud shadows. The left panel shows the real-color image, the middle panel shows the cloud mask (with the red portion indicating the expelled pixels), and the right panel shows the masked real-color image.

Chl-a Concentration Computation

At this stage, the images are ready to be analyzed for chl-*a*. STARS-c presents seven chl-*a* models from the literature in a drop-down menu that can be selected by the user, as shown in **Figure 25**. This drop-down menu is accompanied by a description of each of the models, as well as the model.

The models presented by STARS-c were developed for specific water bodies with their own algal growth limitations and other unique properties. We strongly recommended using or developing a chl-*a* model for the waterbody being analyzed using in-situ data, if possible. If such a model is available, the user can modify the code to use this model. This modification is relatively simple, as users can use the existing models as examples of how to add a new model (or replace an existing model). In many cases, the site-specific model will use the form of one of the provided models and only the coefficients will need to be changed.

chlaModel:	Clear Whole Season	
	Clear Whole Season	
Show code	Clear Early Season	
	Clear Mid Season	
	Clear Late Season	
	Turbid Whole Season	
	Turbid Early Season	
	Turbid Late Season	

Figure 25. Dropdown menu to select a chl-*a* model. Information about these indices is provided in a markdown cell to assist the user in selecting an index.

Error! Reference source not found. shows the code which applies the model selected for analysis. This code shows the names of the Landsat bands that are used in the model definition. We renamed the Landsat bands to common terms because this allows a single model expression to work across the different Landsat missions, which use different band designations.





Metadata

For analysis of long-term chl-a trends, it is useful to retain metadata from the original satellite data. STARS-c retains and exports the date of the satellite image in two different formats, "MM/dd/yyyy", and "MMM dd yyyy hh:mm:ss", this are included in columns titled "Date" and "Date2" in the exported .csv file, respectively. In addition, STARS-c retains and exports the satellite name (e.g., Landsat5 or Landsat8) as a column in the exported .csv file. These data can help analysis completed outside STARS-c using the exported data.

Summary Statistics

STARS-c computes and can export statistical parameters for the waterbody selected for analysis. This is done for each image in the collection that contains data--some images contain no data due to complete cloud cover or other issues. The statistics are for the selected waterbody and only include pixels with viable data but will include any water pixels in the defined geometry, even if they are not part of the main waterbody. Pixels are not included in the statistics if they are

masked; for example, pixels can be masked because they contain land or clouds or are poor quality. The number of pixels included as data for each image is also computed and exported. The number can change for each image, as each image can contain a different number of useful pixels because of clouds or changing water levels that expose or cover shoreline.

STARS-c computes the count (number of pixels used in the analysis for that image or time step), median, mean, standard deviation, minimum, maximum, skew, and the 5th, 10th, 25th, 50th, 75Th, 90th, and 95th, percentiles. The 50th percentile is the same as the median, so it is reported twice. STARS-c computes these data for each image in the collection. When STARS-c exports the data, the two date formats and the satellite which collected the image are also added as columns in the .csv file.

Visualization

STARS-c provides a set of cells to visualize the computed chl-a concentrations as spatial images, and for various masks and other information used in the computation. In addition to an interactive map cell where users can toggle various layers on-and-off, change color ranges, and modify other display characteristics, this cell provides links to images of the various masks and the final chl-a concentration image. These links open the images in individual browser tabs where the image can be viewed, copied, or downloaded.

Exports

STARS-c can export the long-term time series data to a .csv file on the user's Google Drive. The .csv files will be placed in a folder titled "STARS-c_Output". STARS-c exports the data using an asynchronous background process. Depending on the size of the area and the number of images in the collection, this can take some time--it usually completes in about 30 minutes to an hour, though often sooner. STARS-c is not able to show the status of these exports. However, if the user logs into the GEE code editor (which only supports JavaScript), there is a "task" tab which the user can use to determine the status of the export.

The relatively short time required to compute and export these statistics shows the power of using the GEE servers for processing. This process analyzes over 1,000 images for most areas, computes multiple statistics using each pixel in the image, and exports the resulting data. The data are in a format that users, managers, and researchers are familiar with: a .csv file with dates and values in sequence. These data can then be used for further analysis.

Findings

STARS-c Output Examples

The following examples demonstrate the basic use of STARS-c in generating visualizations of chl-a on a waterbody and analyzing time series data. For the time series plots, the median chl-a measurement for the whole lake in each image was used; and data points above a chl-a

concentration of 300 μ g/L were excluded because they are likely bad values that the masks failed to exclude and make graphs unreadable. When analyzing data, STARS-c users should pick their own outlier exclusion thresholds based on the data generated and general knowledge of typical algae concentrations in the waterbody of interest. These examples focus on turbid lakes because the high-turbidity model included in STARS-c has been well-studied.

Lake Taihu

Lake Taihu is a large, turbid, very shallow lake in the Jiangsu province in China. It is an important water resource for the area, but has attracted concern due to intense eutrophication caused by aquaculture in the eastern part of the lake, urban pollutants, and other human-caused nutrient loading.

Figure **27** shows an image from August of 2016 masked and visualized with STARS-c. From these images, it's clear that on that particular day algal blooms were most intense on the northwest side of the lake, with lower concentrations towards the middle.



Figure 27. The polygon-cut real-color image (left), land- and quality-masked image, and chl-*a* image of Lake Taihu in August 2016.



Figure 28 is an example of the type of visualization that can be created with the data exported by STARS-c. The plot shows the median chl-a concentration in every image of Lake Taihu collected

by Landsat over the ~40-year period analyzed. The data are sparser at the beginning of the series because there was only one satellite collecting data—Landsat 5—but as successive missions were launched and old satellites remained operational, the density of the data points increased, leading to more frequent data for later years.



Figure 28. Time series history of median chl-a in Lake Taihu from 1985 to 2022

Malheur Lake

Malheur Lake is another large, shallow lake with high-turbidity water located in eastern Oregon, United States. It has also faced challenges associated with eutrophication and high nutrient loads, and in the Landsat image from August 2013 visualized in

Figure **29**, it is clear that algae biomass in the lake can be quite large.



Figure 29. The polygon-cut RGB image (left), land- and quality-masked image, and chl-a image of Malheur Lake in August 2013.

The time series plot for Malheur Lake, shown in

Figure **30**, shows that the algae concentrations are highly variable but follow a distinct seasonal trend with higher concentrations in the summer, which is to be expected.



Figure 30. A time-series plot of the average chl-a concentration for Malheur Lake over the nearly 40-year period of Landsat data.

Utah Lake

Utah Lake, in the northern part of Utah, United States, shares many characteristics with Taihu Lake and Malheur lake, and is also the subject of much concern over eutrophication. We have conducted remote-sensing and other types of research on this lake prior to the development STARS-c, and with this background knowledge of the lake's ecology and hydrology, the visualizations and time series data generated with STARS-c become much more meaningful and useful. For example, we know that the bay on the east side of the lake (Provo Bay) is very shallow and typically has lower-turbidity water than the rest of the lake. In an image from July of 1986, shown in

Figure **31**, algal concentrations in Provo Bay are higher than much of the lake, so this combined with the likelihood of that water being clearer has interesting implications for our understanding of what factors contribute to algal growth in Utah Lake. In addition, we know that the eastern shore of the lake is significantly more developed than the western shore, so we can examine spatial distributions of chl-*a* within that context to provide further insights into how shoreline development might impact algal blooms.



Figure 31. The polygon-cut image (left), land- and quality-masked image, and chl-*a* image of Utah Lake in July 1986. Grey swirls are regions with high suspended sediemnts, the darker green color correlates with higher chl-a concentrations.

Figure 32 shows the time series plot of chl-a concentrations on Utah Lake. In this case also, prior knowledge of the lake allows us to analyze the data more rigorously. For example, we can examine how past and current river delta restoration projects on Utah Lake tributaries may have impacted algal concentrations in the lake at the outlet of those tributaries, or determine to what extent algal concentrations correlate with the dramatic population growth on the eastern shore that has occurred over the last 40 years.



Figure 32. A time-series plot of the average chl-a concentration for Utah Lake over the nearly 40-year period of Landsat data.

Deer Creek Reservoir

This example was included to show how STARS-c handles a waterbody with clear water and typically low concentrations of algae. Deer Creek Reservoir, in the northern part of Utah, United States, is very deep and clear, with much lower temperatures than the other three lakes; though in recent years the Utah State Department of Water Quality has observed harmful algal blooms and there is some concern over the ecological health of the reservoir.

Figure **33** is a visualization of a Landsat image from July of 1986 and shows that concentrations of algae in Deer Creek on that day were extremely low. The model used to calculate chl-a concentrations for this reservoir was the Clear Whole Season model included in STARS-c, which was developed specifically for Deer Creek using water sampling data, so this model provides more accurates result for this lake than the Turbid Whole Season model used for the other three lakes would.



Figure 33. The polygon-cut RGB image (left), land- and quality-masked image, and chl-*a* image of Deer Creek in July 1986. There is a small cloud and cloud shadow in the northern part of the image that results in the area being masked. Chl-a concentrations in Deer Creek are significantly lower than Utah Lake, which is approximately 25 km downstream.

Figure 34, the time series visualization of median chl-a data on Deer Creek Reservoir, looks quite different from the time series of the more turbid, eutrophic lakes. In this case, it appears that algal concentrations in Deer Creek are typically very low, with the occasional large spike in concentration representing a large bloom. From this graph, it appears that there could be a trend



of increasing frequency for these blooms, however, this may be due to the higher frequency of data in late years, which is the result of more satellites collecting data.

Figure 34. A time-series plot of the average chl-a concentration for Deer Creek reservoir over the nearly 40-year period of Landsat data.

Research Limitations

While STARS-c outputs data as chl-a concentrations, these measurements may not be highly accurate for any given water body due to the limitations inherent in remote sensing. The data can still be useful, though, because the change in concentrations between images or over the long-term should be relatively accurate, and therefore can be used effectively to analyze spatial and temporal trends. To obtain accurate concentrations, the user would need to use in-situ data from the water body to fit a chl-a model specific to that lake or reservoir. While STARS-c provides a long-term history of chl-a concentrations, it is important to understand the dynamics and processes of the specific waterbody of interest. For example, if there is a large nutrient source, such as a waste-water treatment plant, the integrated statistics would not necessarily show that impact. Individual images could show some impact, depending on the size and circulation patterns of the lake, but would not include the long-term trend. Users can place smaller geometric regions around a lake, isolating various areas, and generate the long-term statistics for that area. These segments can then be used to compare different regions of the lake or to compare a small area to the larger lake as a whole in order to provide better insight into spatial variation.

Originality and STARS-c Value

STARS-c allows water managers and researchers to visualize, evaluate, and analyze long-term trends in chl-*a* concentrations in waterbodies across globe. It runs in a browser and uses cloud resources, meaning that STARS-c is not resource constrained and requires minimal computational infrastructure. Access to STARS-c is available upon request.

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The Study of Clean Water and Sanitation in Bunyenye and Bunyaka Villages in Luwero District SDG 6

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Abstract

Water scarcity affects over 40 percent of the people in the world. Although 2.1 billion people have improved water sanitation since 1990, dwindling drinking water supplies are affecting every continent. In Uganda, safe and affordable drinking water for all by 2030 requires investing in adequate infrastructure, providing sanitation facilities, encouraging hygiene, as well as protecting and restoring water-related ecosystems. Uganda has experienced two decades of economic growth, and there were also other factors leading to large population movement from rural to urban. However, the reversal of the trend of urban to rural migration occurred due to the coronavirus (COVID 19) and the lock down resulted in large numbers of people returning to villages which led to increased population figures and hiking the rates of poor sanitation and water pollution. Luwero District has an average per-capita consumption of 14 liters per a person per a day which is below the Ministry of Health recommended consumption of 20 liters per a person per a day. This paper explores perceptions and recommendations of the community on the challenges faced concerning water and sanitation and their solutions. The study objectives were to find out the number of water collection points, the distance to these water sources, status of these water points, adequacy of the water and remedies to the challenges. The study results showed that there were inadequate and poorly maintained water points in this community. We recommend a concerted effort of community awareness and sensitization to maintain and improve the available water points and full Government intervention in the water and sanitation issues under SDG 6.

Keywords: Water, Sanitation, Hygiene, Water Points, Health and Wellbeing, COVID 19

Introduction

Access to safe water, sanitation and hygiene, and water resource management are critical for human health, environmental sustainability, and economic growth. In acknowledgement of this, the General Assembly supported Sustainable Development Goal 6, guaranteeing the sustainable consumption and production patterns management of water and sanitation for everyone, as part of the 2030 Agenda for Sustainable Development. Six targets and nine important indicators comprise Goal 6, with drinking water, sanitation, and hygiene taking center stage. This paper looks at Goal 6 and how it can be implemented around the world.

Purpose

The project aims at addressing the issue of enhancing community awareness through sanitization, improving and maintaining the quality of existing water sources, as outlined under SDG 6 Clean Water and Sanitation. This issue is important because it will help to empower communities on managing and maintaining water points, improving water harvesting and collection points, empowering community on water purification methods as well as promoting the Implementation of IWRM (Integrated Water Resources Management).

Background Literature

For several decades, water specialists have talked about a "global water crisis," as have politicians and the general public in the last five to ten years. What exactly is this crisis? Is the world about to run out of water? Is there a lack of investment in making water accessible to people? Large investment in utilization of water resources occurred over the twentieth century (Kurian *et al.*, 2019). Although the world's population quadrupled in the previous century, water use4 increased sixfold. The governments of the United States and Australia, for example, built 5,000 cubic meters of water storage facilities for each of its residents. The majority of this infrastructure is intended to generate hydroelectricity and irrigate farmland, while some are intended to regulate floods and store water for residential water supply in urban areas. More money has been put into water distribution infrastructures, treatment facilities, sewage, and waste water treatment (Tortajada & Biswas, 2018).

Many people characterize "the water crisis" as a lack of access to clean and inexpensive water for over a billion people, as well as a lack of access to reliable and cheap sanitation for about half of the world's population. As a result, impoverished people suffer from diarrhoeal infections, which kill around two million people each year, the majority of them are children under the age of five (Komarulzaman, Smits, & de Jong, 2017). Others see the situation as impoverished and hungry people in rural regions lacking access to water to cultivate food and support their livelihoods. Three-quarters of the world's 1.2 billion impoverished and 800 million malnourished people reside in rural regions, with subsistence agriculture serving as their major source of food and income. There is definitely enough water in the globe for residential use, industry, and even food production; yet, these water resources are spread quite unevenly, and there are big, heavily inhabited areas with either poor water supplies or water dropping very unevenly throughout the year (Boretti and Rosa, 2019).

Methodology Used

The research paper used both qualitative and quantitative methods of research. Qualitative research was got from review of books, journals, papers et c while the quantitative method used several zoom meetings, phone calls, face to face interactions, focused group discussions, interviews and questionnaires.

Originality/Value of the Paper

The project paper has never been authored by any other person and it is an authentic work of the project team of (Sustainable Development Goal 6 Clean Water and Sanitation). In addition, the paper follows ethics of research and all the information collected from the field will only be used for the purpose of the research.

Findings/Discussion

The study was carried out in Bunyenye and Bunyaka villages in Luwero District. The team was focused on reaching out to the community to generate relevant information about the water and sanitation situation.





Ratios per Village per Gender:

Bunyenye (female 26, Male 24) and Bunyaka (female 29, Male 21)





From the above graph it is clear that majority of the women that took part in this research were between 36 and 50 years old. The means that most of the elderly women are the one that take part on the search for water for their families.





Majority of men that took part in the study were between 26-30, an age bracket mostly comprising those that are not married and would be looking for water on their own unlike their counterparts who are married and have left that duty to their wives.

The number of people living per household in the mentioned communities are 5 to 18 members these include; father, mother, children, grandchildren, grandparents, uncles, and aunties.

Household Income

The Average Income of the Household:

The respondents were not receptive to this question. They found it difficult to disclose their financial statuses. 42% of the respondents were welcoming to the question were mainly subsistence farmers.

Availability of Water Sources

The period the respondents have been in these communities includes; 48 people have been residents of these communities for 40 years, 22 people between 20-30 years and 30 between 10-20 years. The available water points for both Bunyenye and Bunyaka villages are; boreholes, shallow wells, harvested rain water, springs, and dug wells. These are the available water points that are used for all domestic activities. Most of them are access to the villages.

We also discovered that the main point of drinking water that people use in these communities are bore holes, which serve 60% of the village populations.

Distance to Water Points

The residents explained that they move about 1-2 kilometers to get to these water collection points. We managed to see the water points and to our observation, we discovered that; The distance to the water point is approximately one kilometer or even more depending on where the person is coming from which the farthest is 6 kilometers away. The distance to the water point makes it difficult for families to have water all the time in their homes. Families that have only the elderly people find it hard to move from home to the water point.

Water adequacy in these communities; have adequate water during the rainy season, however during the dry season, these water points don't have water at all. The water levels tend to go down and it becomes difficult to get access to water, yet the communities depended on these water points. The breakdown of bore holes also makes it difficult to always have adequate water. About 12% have piped water that is bought from the few people that have piped water is very expensive. The rain harvested water is unreliable because it happens between Febraury and April and sometimes in August. Due to lack of water in the home, poor sanitation becomes an issue where by most domestic activities cannot be carried out like mopping of housing, washing clothes, cooking, etc.

Water Movement from Source

Means of water transportation from the water points (water collection points) to homes; water is commonly fetched and transported by the young children of 8-12 years and women to their homes. They carry the jerrycans of water on their heads to their homes, a few families that have bicycles help make it easy for them to transport the water. The use of children to fetch water affects their education as they have to come from school go to fetch water and run back to school

during lunch break and in most cases, they end up going back to school. In addition, this also affects their security as they are young and move long distances in search of water.

Quality of Water

The quality of water in the water points; **r**esponses from the communities indicated that these water points are not clean and do not have the best water for drinking. However, they are all they have. People and animals use the same water points and animals tend to put dung in the water points making the water not safe for home use. Brick makers next to the water points make it dirty and most time use the water excessively and the water points run dry and the authority have policy in place to deal with such people.

The residents informed us that they do try to maintain the available water points by draining, rubbish picking, fencing with sticks or wood and slashing the bushes around water points that is organized by the local leaders (LC1).

The communities shared some of the methods that are used to purify water that is got from the water points, these include boiling and filtering.

Challenges at the Water Source

Some of the challenges faced while using these water sources include; the water points are known for accidents as young children below 18 years are at risk of drowning in the wells. In addition, long distance to the water points makes it difficult for all homes to have adequate water. It was also revealed that dirty, unsafe water which may contribute to the spread of diseases like diarrhea and typhoid. Among the challenges is harassment of most girls and women by men. There is high maintenance fees for the bore holes and piped water and the brick makers that share the same water points making it dirty. It was also revealed that the floods from the running water during the rainy season make the water points dirty. Finally, dug wells don't have enough water as they tend to dry up during the dry seasons due to the many people that use them.

Possible Solutions to the Challenges

Led by the government there should be fencing off the water collection points to prevent accidents. Establishment of new water collection points. Carry out water purification for the available water points. Create rules, laws and protective strategies for the water points that protect both girls and women from being harassed, including raped. To re-channel the floods from the running water that enters the wells. Filtering and boiling of the unsafe water and finally, slash around the water points.

Responses from the Community Leaders

These are some of the Responses we Collected from the Community Leaders of Both Bunyenye and Bunyaka Villages

We managed to interview five community. From our observation, these leaders have been in these communities for at least 5 years. They were eligible to give the accurate information needed on the status of water and sanitation in these communities.

Some of the challenges that the leaders and the community members face with water in these communities include; limited water sources in the village, poor water quality, long distance to water points, inadequate water storage facilities, pollution of the water sources and poor maintenance of water points.

Some of the solutions that were generated from the community leaders include;

Building new water points, community sensitization on how to maintain water points, Community sensitization on water storage, improving the drainage system, draining the polluted water points, fencing of the water points (however, the community members don't have the funds to perform this activity), mending broken boreholes (they don't have the funds) and government involvement in the water and sanitation issues in the community through providing expertise to mend and build boreholes.

Research Limitations/Implications

Research constraints included; minimum resources while carrying out the survey which backlogged the community fieldwork hence opting for virtual means of communication which supported our research, lack of full community participation as a result of lack of enough publicity and awareness. This made it difficult to penetrate to certain households and even some of those that we reached out to, were hesitant to providing us with enough information. The COVID 19 pandemic was a huge set back to our research as well as the imposed curfew time could not enable us to reach out to some of the communities hence making our respondents inaccessible.

Recommendations

After looking at the research presented in this paper and findings of the study the following recommendations were proposed;

i. Improving and maintaining the quality of the water points in Bunyaka and Bunyenye villages in Luwero district, requires the need to enhance community awareness through sensitization, improving and maintaining the quality of the water points, improve water harvesting, collection points and storage facilities, empower community on water purification methods, and to promote the Implementation of IWRM (Integrated Water Resources Management) under SDG 6.

- ii. Improve sanitation by installing toilets and sanitation facilities that flush into a sewer or a secure enclosure.
- iii. Education can help to promote excellent hygiene practices. Hand washing with soap and water can cut diarrhea cases by up to 35%.
- iv. Install rainwater collection and storage devices to gather and store rainwater for drinking or refilling subterranean aquifers. Create wells to obtain groundwater from aquifers underneath.
- v. To make drinking water safe, provide household water-treatment capabilities via filters, sun disinfection, or flocculants.
- vi. We advise using individual filter straws. With the exception of salt water, these practical small-scale solutions enable people to drink water from almost any source. Utilizing a very small medium that traps debris and germs inside its pores, the device creates clean, drinking water by circulating water through it. Up to 99 percent of germs and other impurities in water are eliminated by the personal filter straws.
- vii. To enhance water quality, promote low-cost options such as chlorine pills or plastic bottles that may be exposed to sunshine.
- viii. Rainwater collection is essential. Humans have been collecting rainwater from surfaces where it falls and storing it as a result for hundreds of years. It is an efficient technique to lessen dependency on other water sources and to offer water in isolated rural locations that might not have access to regular water supply.
- ix. Finally, the government or other partners, such as NGOs, should supply smart irrigation controls to farmers in these two communities. This technology helps irrigation system owners set an effective water schedule to maintain healthy plants and remotely operate their systems using smart devices, improving irrigation system water usage efficiency. It allows for the conservation of the scarce water resources and is especially helpful in locations where there is a water shortage.

Conclusion

In conclusion, being able to prevent exposure to a variety of illnesses requires access to clean water and sanitary facilities. Millions of people perish each year from illnesses brought on by poor water quality, sanitation, and hygiene. This paper has revealed that there are inadequate and poorly maintained water points in these community. Amongst its recommendations the study recommends that the government engagement in the water and sanitation issues under SDG 6 as well as a combined effort of community awareness and enlightenment to maintain and enhance the existing water points. Access to clean water and sanitation as well as sustainable

management of water resources are crucial for maximizing economic output and yielding large returns on current investments in health and education.

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Appendices

Appendix I: Questionaire

Consent

I agree to be part of this study.

- Yes.....
- No.....

Demographics

1). The gender of the head of the household:

- Male.....
- Female.....

2). Age of Respondent

- Less than 18.....
- 18-25.....
- 26-30.....
- 31-35.....
- 36-40.....
- 41- 50.....
- 51 and above.....

3). Number of persons in the household.

.....

4). Average income of the households (in the last two months)

.....

5). How long have you lived in this community? (years)

.....

••••••

Knowledge, Attitude and Practices (Water)

1). What are the available water sources in this community?

- Boreholes.....
- Shallow wells.....
- Piped water.....
- Harvested water.....
- Pumped water.....
- All the above.....
- Others.....

2). Of the above, where does your household mainly draw water from?

.....

3). What is your main source of water for drinking?

- Boreholes.....
- Shallow wells.....
- Piped water.....
- Harvested water.....
- Pumped water.....

- All the above.....
- Others.....

4). How far is the water source from your home in kilometers?

.....

5). Do the water sources always have adequate water?

- Yes.....
- No.....

6). What are the means of water transportation to your homes?

- Bicycle
- Car
- Carrying on the head

7). What is the quality of the water sources in this community?

- Always Clean
- Sometimes clean
- Not clean

8). Do you maintain these water points?

- Yes
- No

9). How do you maintain these water sources?

• Draining

- Fencing
- Rubbish picking
- Slashing the bush
- All the above

10). What are the possible methods you use to purify the water?

- Boiling
- Sieving
- Water purifiers

11). What challenges do you face while using these water sources?

.....

12). What are the possible solutions you have to these challenges?

.....

13). How do you store water from the water source?

.....

Sanitation

1). What facilities for fecal disposal do you use in your household?

- Open space
- Latrine
- The bush
- Others(specify)

2). Do you have a latrine?

- Yes
- No
- 3). How do you dispose waste in your household?
 - Use of a dustbins
 - Burning
 - Burying
 - Recycling
 - Used at the farm
 - Others(specify)

4). What challenges do you face in maintaining sanitation and cleanliness?

.....

.....

5). What suggestions do you have in solving the above challenges?

.....

NOTE 2: The following questions were posed to the community leaders of both Bunyenye and Bunyaka villages.

- 1). Do you hold any leadership position in your community?
 - Yes
 - No

2). What is your leadership position in this community?

.....

3). How long have you lived in this community? 4). What are some of the challenges that you face in this community? 5). What are some of the challenges the community faces concerning water? 6). As a leader, what are some of the solutions that you have come up with to help the people in this community? 7). How has the government been helpful concerning these challenges? 8). What other engagements have you had with other organizations concerning the situation of water and sanitation in this community?


Achieving Sustainable Development Goal 6 in India: Transforming Lives through Localization

Siddharth Singh (India)

Abstract

In 2015, 63.3% of Indian rural households and 19.7% of urban households did not have access to improved sanitation measures. World Bank has noted the severity and urgency of the situation by observing that more than 520 million people in India were defecating in the open. The adoption of Sustainable Development Goals (SDGs) aligned with the Indian national development agenda concerning improved water and sanitation measures proved remarkably successful in the previous years. India has established an SDG localized model for adopting, implementing, and monitoring SDGs at national, sub-national, and local levels. SDG 6 deals with ensuring availability and sustainable management of water resources and sanitation for everyone has been translated into multiple governmental policies in India. The Indian government, under its flagship program, Jal Jeevan Mission (National Water Mission) is committed to providing safe drinking water through individual household tap connections by 2024 to all households in rural India. Likewise, another prominent scheme of Swachh Bharat Abhiyan (Clean India Mission) demonstrated success by providing access to toilet facilities in the rural households and achieving the target of Open Defecation Free (ODF) in all the districts. With the help of a series of social welfare schemes and their continuous monitoring at all levels, India is making significant progress in achieving SDG 6. For these reasons, the Indian Goal 6 experiences become crucial for other countries and provide numerous learning opportunities for them.

Keywords: India, Localization, SDGs, Sanitation, Sustainability, Water

Introduction

India is the second-most populous country in the world with a population of approximately 1.39 billion. Considering its large and increasing population, India has always witnessed huge water demand in multiple sectors, including domestic, agriculture, energy, and industries (Soumya et al., 2020). However, this massive water demand becomes critical in the light of India's limited water resources and plenty water scarce regions. Agricultural fields of the northern India majorly rely upon Himalayan river system. However, as the water flow decreases downstream, it causes water scarcity in the plains (Soumya et al., 2020). Similarly, the irrigation sector is largely dependent upon groundwater however its excessive and unsustainable extraction has led to significant depletion in its levels.

Among all, inadequate sanitation measures poses one of the massive threats to the availability of clean and safe water resources. Data suggest that around 2 billion people worldwide are drinking water from the sources contaminated by the fecal matter (Soumya et al., 2020). In the absence

of proper toilet facilities, the practice of defecating out in open and public spaces prevails both in urban and rural areas. India alone accounts for 57% of the global population defecating in open. According to the 2011 census data, national sanitation coverage was 46.9%, while rural sanitation coverage was restricted up to 30.7%. This figure continues to shrink even further when we look specifically into the coverage data of backward and tribal communities (Sujith, 2016).

Before 2014, around 568 million people in India were facing the indignity of defecating in open and public spaces due to lack of access to toilets (UNICEF). Such practices were more prevalent among the poorest citizen who could not afford household water connections and toilets. Moreover, people believed it to be impure and unhygienic to construct toilets inside houses. As per 2013-14 rapid survey on children, 22% of the Indian schools lacked toilet facilities for girl students. Likewise, around 54% of the preschools had no toilet and water arrangements on their premises (UNICEF). Half of the population does not have an access to safely managed drinking water. In 2015, 63.3% of Indian rural households and 19.7% of urban households did not have access to improved sanitation measures. High quantities of harmful chemicals like arsenic and fluoride could also be found in 1.96 million dwellings.

The practice of open defecation is detrimental for the health and well-being of the local population and the environment. The absence of adequate water and sanitation facilities and care for personal hygiene are threat to serious illness and water-borne diseases. Inappropriate human waste disposal tend to increase the risks of diseases, including cholera, typhoid, dysentery, hepatitis A, polio and other infectious diseases. India witnessed 100,000 diarrheal deaths among children below five years of age. It also causes significant impact on the women's health and often leads to violence against women. Women who are forced to move out of their house to find private spaces for defecation are more prone to physical and sexual abuse (Mahrukh et al., 2019). UN Human Rights Council has noted that more than health and crimes, open defecation is also linked with the infringement of dignity of an individual and is a human rights issue (HRC, 2009). In an environmental law case, the Supreme Court of India has observed that the failure of the municipalities in providing public conveniences forces slum-dwellers to defecate in open places and thus crucial for human dignity (Municipal Council, Ratlam v. Shri Vardhichand and Others, [1980]).

After the adoption of Sustainable Development Goals (SDGs) clubbed with Indian domestic policies on water sanitation and hygiene (WASH) the overall situation has drastically improved and appeared promising for the future (Sarkar and Bharat, 2021). UNICEF notes one of the ambitious Indian program, *Swachh Bharat Mission* (SBM), that progressed the country towards achieving SDG 6.2. It resulted in the construction of over 100 million household toilets in 630,000 villages, with an aim to provide access to sanitation to all. It helped in reducing total number of days of illness, preventing soil and water contamination and creation of around 7.5 million jobs under the scheme (UNICEF, 2018; UNICEF, 2019). Likewise, range of efforts and collaboration from central level to the grass-root level has played a significant role in the betterment of the previous situation. The paper attempts to trace the journey of SDG 6 (water and sanitation) since its adoption to the present-day implementation. After introducing the issue in the first part, the second part describes the status of right to water and sanitation existing in India before 2015. In

the third part, the paper explores the relationship between India and Sustainable Development Goals (SDGs). The fourth part illustrates the localization of SDGs as practiced in India for achieving the Agenda 2030. The paper further discusses SDG 6 in the Indian context and point out the progress and lessons from the fifth part. Lastly, it ends by commenting upon the efficiency of Indian practices and its role towards achieving SDG 6.

India before 2105

Securing water and sanitation demand has remained India's priority since its independence in 1947. India has established massive infrastructure and institutional arrangements to fulfill its goals. Construction of dams and irrigation canals helped the country to meet its water uses as well as to generate hydro-electricity. They further allowed India to overcome geographical challenges like controlling floods and providing water in water-scarce regions (Soumya, 2020). In its efforts to progressively achieve the full realization of international legal provisions, India became party to multiple environmental and human rights treaties that promotes rights concerning water and sanitation to its citizen. Considering its large population, continuous and uneven water needs, India moved forward in the direction of fulfilling water and sanitation requirements. In this context, the reports suggest that Indian actions for the Millennium Development Goals (MDGs) have effectively addressed the issue of water (UN, 2015).

Though the Indian Constitution does not expressly refer to water or sanitation rights, however, article 262 that deals with the resolution of state river water disputes specifies water rights as riparian rights (NHRC, 2021). India has enacted several laws relating to water pollution, water supply and water resources management, including Indian Easements Act, 1882, Water (Prevention and Control of Pollution) Act, 1974, and the Environment (Protection) Act, 1986.It also adopted National Water Policy in 1987 and revised it in 2002 and 2012 to ensure effective management and supply of water resources. Notably, these legal documents did not focus on the rights aspects of water and sanitation. Likewise, there exists no statute dealing with sanitation or right to sanitation however issues concerning sanitation and dignified life were expressed in various domestic legal texts.

The Indian judiciary has played an active role in interpreting right to access to clean and pollutionfree water within a broader head of the right to life under article 21 (Subhash Kumar v. State of Bihar, [1991]; Vellore Citizen's Welfare Forum v. Union of India, [1996]; State of Karnataka v. State of Andhra Pradesh, [2000]).Similarly, the apex court recognized sanitation as an essential part of enjoying right to life with human dignity (Virendra Gaur v. State of Haryana, [1995]; L. K. Koolwal v. State of Haryana, [1988]). Further, it is established that state is responsible to provide clean drinking water to its citizen (M. C. Mehta v. Kamal Nath, [1997]; P. R. Subhash Chandran v. Government of Andhra Pradesh & others, [2001]). Likewise, it is basic duty of municipalities to provide drainage system in working conditions to sufficiently meet the needs of the people. (Municipal Council, Ratlam v. Vardichand, [1980]). Moreover, the courts have even highlighted the rights of the sanitation workers (Delhi Jal Board v. National Campaign for Dignity and Rights of Sewerage and Allied Workers and others, [2011]) and stress for the monetary compensation in case of sewer deaths (Safai Karamchari Andolan v. Union of India, [2014]).

India and Sustainable Development Goals (SDGs)

By the end of 2015, lack of access to clean drinking water and inadequate sanitation measures posed significant challenges to the well-being of Indian population. Its impact was largely felt by different vulnerable groups, including women, children, elderly, and the poor. Though water related MDGs demonstrated success within the Indian context, the primary challenge before the post-2015 framework involved the elimination of inequalities within the supply and access levels of water and sanitation services. Moreover, MDG target 7c that ensures sustainable access to safe drinking water and basic sanitation does not refer to the water quality. The term 'safe drinking water' is primarily employed in context with an improved source of water, for instances, piped water and not water quality. For this reason, despite emphasizing on 'safe drinking water', 41.5% water samples from urban households and 60% water samples from rural households were found to be contaminated (Mira et al., 2014).

The adoption of 2015 Sustainable Development Goals (SDGs) immensely aided the existing national water and health policies of India. The motto of SDGs, "Leaving No One Behind" is mirrored in the India's national developmental agenda of 'Sabka Saath, Sabka Vikas, Sabka Vishwas, Sabka Prayas' (Collective Support, Inclusive Growth, Collective Trust, and Collective Efforts). India has introduced many social welfare schemes and programs that are related to several SDGs. For instance, in 2018 the Indian government launched the world's largest health protection scheme, namely Ayushman Bharat-Pradhan Mantri Jan Arogya Yojana (PMJAY) that provides annual health protection of approximately US\$ 7,100 to 500 million citizens. This initiative aims to overcome expensive health expenditures for poor population and reduce inequality. India is aiming to eliminate tuberculosis by 2025 that is five years ahead of the global target of 2030. Another welfare scheme, Poshan Abhiyan (National Nutrition Mission) launched by the government aims to eliminate malnutrition by 2022. The program further considers the linkages between nutrition and other aspects relating to water, sanitation, hygiene, poverty. Similarly, India has often stressed upon the need for securing climate justice and aims to eliminate single-use plastic by 2022.

India is committed to implement the SDGs through nationally defined parameters drawn in accordance with national priorities and needs. For this purpose, NITI (National Institution for Transforming India) Aayog, an apex public policy think tank of Government of India, has mapped out existing domestic central and centrally sponsored schemes and their concerned ministry or department against each target of SDGs (NITI Aayog, 2018). For instance, the SDG Target 6.1 seeks to achieve universal and equitable access to safe and affordable drinking water by 2030. The NITI Aayog has associated Target 6.1 along with the 2009 launched National Rural Drinking Water Program (NRDWP) that aims to provide safe and adequate water for drinking, cooking and other domestic needs to every rural person on a sustainable basis. The Department of Drinking Water and Sanitation and Ministry of Women and Child Development is entrusted to achieve the scheme objectives and ultimately, Target 6.1. Similarly, Target 6.2 requires achieving access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations. To achieve Target 6.2, the Aayog has referred to its existing *Swachh Bharat Mission (Rural)*, *Swachh Bharat Mission*

(Urban) and the Mission for Protection and Empowerment of Women. Simultaneously, it has ensured the responsibility of the governing departments, including Department of Drinking Water and Sanitation, Housing and Urban Affairs, Ministry of Rural Development, Ministry of Women and Child Development and Panchayati Raj to achieve these targets.

India is a Union of States comprising federal structure with a strong center. The Indian Constitution has demarcated the functional subject matters of both center and state governments under Schedule VII in the form of three lists - Union List, State List, and Concurrent List. Further, there exists a three-tier local governance system at the sub-state level. Along with the efforts made by the central government, SDGs are being achieved with the continuous support of sub-national governments. Considering the federal governance structure of India, the 28 Indian States and 8 Union Territories (UTs) account for majority of the roles and functions in this direction. These state and local governments look after the planning, execution and monitoring phases of the SDGs. They work at the grass-root levels by directly engaging with the local communities to fulfill the Indian commitments for the 2030 Agenda. This arrangement makes the sub-national governments a key player in the fulfillment of SDGs.

Since the Indian States and Union Territories differ in terms of population, geographical features, natural resources, and education and health standards, therefore the sub-national governments have to undertake special care particular needs and demands of the local citizen while implementing the global SDGs. It led the local governments to pursue the localization of SDGs resulting in effective results from across the country (NITI Aayog, 2019).

Localization of SDGs

'Localizing' could be understood as the 'process of recognizing sub-national contexts in the achievement of the 2030 Agenda, from the setting of goals and targets, to determining the means of implementation and using indicators to measure and monitor progress, in addition to raising awareness through advocacy' (NITI Aayog, 2019). It aims to identify the approaches of the local and sub-national governments to realize SDGs through the bottom up actions and to ascertain the role of SDGs in devising a framework for the local development policy. Localization of the SDGs is the responsibility of all the three-tiers of Indian government.

The First Phase

The India experience of localizing the SDGs can be divided into three on-going phases that often occurs together (NITI Aayog, 2019). The first phase discusses about identifying institutions and assigning specific mandates in relation to SDGs. Based on the three-tier governance structure, the allocation has been done at three levels – Central, State, and District. Major institutions existing at the central level include NITI Aayog (successor to the erstwhile Planning Commission), Ministry of Statistics and Program Implementation (MoSPI), Central/Federal Ministries, and Comptroller and Audit General of India. NITI Aayog is responsible to ensure coordination between the Ministries and the State governments and to monitor the progress of the Goals. MoSPI was designated to realize the formulation of the National Indicator Framework (NIF) essential to track

updates in SDGs. Similarly, to discuss the roles of Ministries, SDGs and their targets have been linked with the domestic welfare schemes and the concerned Ministry or Department is required to ensure its fulfillment. Lastly, the Comptroller and Audit General of India is the apex audit body and it is mandated to conduct audit on the preparedness to achieve the SDGs. In addition, the Finance Commission of India, National training institutions, and the Legislature has demonstrated their specific role with respect to the 2030 Agenda (NITI Aayog, 2019).

At the State level, the Office of the Chief Secretary of the State has been assigned the duty to guide and oversee the matters concerning SDGs. The Chief Secretary is the top official of the State administration who also acts as a chief advisor to the Chief Minister of the State and Secretary to the State's cabinet. Line departments are mandated to prepare, implement, and monitor programs for the realization of SDGs. Further, the Planning Department and Directorate of Economics and Statistics are also involved to look after the SDGs implementation and collect crucial data for this purpose (NITI Aayog, 2019).

The Indian government structure goes further deeper to the sub-state or district level. There exist a three-tier rural local self-governance system comprising – Panchayat at the village level, Urban Local Bodies at the block level, and the District administration at the District level. The elected representatives of all these sub-state bodies are responsible to fulfill the obligations concerning SDGs at the level. In this manner, the institutions have been identified till the lowest administration level and further included in task of accomplishing SDGs.

The Second Phase

The second phase of SDGs localization emphasizes raising awareness and advocating for SDG implementation. Awareness is crucial for bringing behavioral changes among the participating actors. It ensures effective implementation of policies and creates ownership of SDGs among different stakeholders. For this purpose, the NITI Aayog being the primary body for co-ordination actively worked to sensitize the stakeholders towards SDGs.

The Indian Government took several initiatives to increase interests and commitment of all the partners on SDGs. *Firstly*, the NITI Aayog created a shared understanding among the Central and State level governments to increase their sincerity and dedication towards achieving SDGs. For this purpose, it organized national and regional consultations on each SDG except Goal 17. It invited the Ministry departments, State governments, external experts, CSOs and the United Nations to the national consultation. Along with these consultations, it also organized National Workshop on Building Capacity for Localizing SDGs. *Secondly*, the NITI Aayog played an active role in mapping every SDGs and their targets with a centrally sponsored scheme and dedicated Ministry to follow a 'whole-of-government' approach. In this way, the Aayog entrusted responsibility of achieving specific target with a particular Ministry and ultimately leaving no target unaddressed. *Thirdly*, as a torchbearer of SDGs sensitization, NITI Aayog came up with designing SDG India Index Baseline Report Dashboard in 2018. It was a composite Index having 62 indicators across 14 SDGs that listed and ranked the progress of every State and Union Territory on SDGs. It was an attempt to establish an advocacy and benchmark tool and to increase the

spirit of competition among stakeholders and motivate them for improvements. *Lastly*, the Ministry of Statistics and Program Implementation (MoSPI) was entrusted with a job to develop National Indicator Framework (NIF) to monitor SDGs. For this purpose, the MoSPI created nationally-relevant indicators and circulated them among various stakeholders for their observations followed by public consultation. Consequently, through this participatory process, a National Indicator Framework was developed with 306 indicators based on the remarks of Ministries, States, and concerned UN and other bodies. It is a crucial tool to track the progress of SDGs at the national level and further to guide policy makers and executives toward SDGs implementation (NITI Aayog, 2019).

The Third Phase

Considering the geographical, socio-economic, cultural, demographic diversities among the States, they play a crucial role in the localizing of SDGs. The third phase addresses many initiatives aiming to strengthen the implementation of SDGs by developing upon their localization. First, it includes that after the mapping and designating Ministries for specific targets, the line Ministries identified strategies to align their plans with specific goals and monitor them. For instance, the Ministry of Panchayati Raj advised local government to employ SDGs within their governance plans (village development plans). Second, the SDGs should be understood and realized in local contexts. The national level consultations and discussion on SDGs clarified its thematic details and allowed the sub-national governments to open regional consultations for more detailed analysis on the implementation of targets at sub-national levels. It allowed them to conduct workshops local government officials, rural communities, civil society organizations and others. Third, the governments should advance indicators and metrics and institute monitoring mechanisms to keep a track of policy direction and implementation progress. On the basis of inclusive consultations, the MoSPI established NIF that acts as a data sources for implementation of SDGs. Similarly, States are advised to draft State-specific indicators to track their actions. Fourth, the State and UT governments should establish their own policy and strategy framework to SDGs. Due to the critical role of States in achieving SDGs, the NITI Aayog developed State level Vision documents and SDG Action Plans relating to SDGs. Further, it encouraged the States to identify a nodal department to co-ordinate at the State level and map existing government schemes with the SDGs. The mapping process is also helpful in ascertaining any gaps in the existing policy framework so that they can be adjusted with other required action plans. Moreover, the Aayog stresses State's to develop capacity development initiatives and budget planning and allocation for SDGs.

States have actively taken part in organizing implementation system for SDGs. 31 States and UTs have defined their nodal agency for coordination, generally being the Department of Planning in many cases. Some of them have even defined nodal structures to be followed within various departments. While 23 States and UTs have prepared the Vision document, the others are working on its development. Most of them have followed 'whole-of-government' approach and working on aligning budget to State specific SDG target. Further, similar to NITI Aayog at the central level, States are also undertaking periodic reviews on the implementation mechanisms by concerned State Departments and sub-national governments.

After 2015, in the first four years, the Centre, State and District level governments have emphasized primarily upon developing roadmaps and monitoring mechanism towards SDGs. Gradually, they are on the move to make SDGs as the core developmental framework where all the planning and policy making should address its targets. The early lessons deriving out of the localization of SDGs are promising. They provide unique opportunity to strengthen the Indian federal structure and commit social justice to the rural, deprived and marginalized segment of the society (NITI Aayog, 2019).

Sustainable Development Goal 6 in India

Sustainable Development Goal 6 aims to ensure availability and sustainable management of water and sanitation for all. It is determined to secure safe, affordable and accessible drinking water, sanitation facilities and hygiene for every person by 2030. The goal is focused upon reducing water pollution, increasing water-use efficiency, and promoting participation of local communities in improving water quality.

Goal 6 consists of eight targets dedicated to improved instances of water and sanitation measures. It includes universal and equitable access to safe drinking water (6.1); access to equitable and adequate sanitation, ending open defecation, and promoting women and girl hygiene (6.2); improving water quality with recycling and safe reuse and minimizing water contamination (6.3); increasing water-use efficiency and addressing water scarcity through sustainable withdrawals (6.4); implementing integrated water resource management at all levels (6.5); expanding international cooperation and capacity-building support (6.a); strengthening the participation of local communities in water and sanitation management (6.b)(UNGA, 2015). All these targets are expected to be secured before 2030, except Target 6.6 that seeks to protect and restore water-related ecosystem by 2020.

India has recently released SDG India Index 3.0 that measures its progress on SDGs. As per the Index, eight national level indicators have been identified that address five out of the eight SDG 6 targets (NITI Aayog, 2021). These indicators were selected based on the data available at the sub-national levels and that can ensure comparability among the States and UTs. With the help of these indicators, the performance of all the Indian States and UTs has been recorded and ranked through SDG Index Score. As per this Score, the Indian States of Goa and the UT of Lakshadweep scored the highest 100, where the score of other States ranged between 54 and 96 and the score of the UTs ranged between 61 and 99 (NITI Aayog, 2021).

These indicators present a highly promising picture of Indian achievements on SDG 6. According to the Index, Indian States have constructed 100% Individual toilets in rural households. Moreover, in 2020, it verified all the Districts of India as Open Defecation Free (ODF). With reference to access to safe and adequate drinking water, 51.36% of the rural population has become the beneficiary of PWS and 97.44% of the rural population has access to improved water source of drinking water. In comparison to 2013-14 reports when 22% of the Indian schools lacked toilet facilities for girl students, today 95% of the schools have a separate toilet facility for girls. The target is to cover all the schools in the country.

An independent survey conducted by UNICEF finds that households in ODF villages have accumulated the benefits of 50000 Indian rupees. It further highlights the benefits of SBM as reduced medical expenditures, time saved from illness, lowering in mortality rates and increase in the property value with the construction of toilets (UNICEF, 2018). Likewise, in another study, UNICEF founds that ODF villages have more access to contamination-free soil and food (UNICEF, 2019).

Similarly, presently 88.4% of high polluting industries comply with waste-water treatment as per Central Pollution Control Board (CPCB) norms. North-Eastern States of India including Manipur, Nagaland, and Tripura has accomplished this target. The target is to ensure that all the industries comply with the wastewater treatment norms. With regards to the groundwater withdrawal, a stage of 70% or less is treated as safe. India stands at an overall groundwater withdrawal of 63%. However, States like Delhi, Haryana, Punjab, and Rajasthan pose a challenge where the groundwater extraction is significantly high. They have an extraction percentage of more than 100 indicating that their annual groundwater consumption is more than the extractable ground water resources. Other large and densely populated States like Uttar Pradesh, Tamil Nadu and Himachal Pradesh also range between 70% and 100%. It is desirable that the figures in these States should be reduced below 70%. Adding to it, presently, 17.24% of the Blocks are considered as over-exploited and the target is to reduce this figure to 0.

Effective Welfare Policies on Water and Sanitation in India

Among the other SDGs, India made notable success in the field of water and sanitation. The scenario changed drastically between the years 2016 to 2019. With the help of two of its major schemes, India could achieve SDGs ahead of 2030. The Indian government, under its flagship program, *Jal Jeevan Mission*, is committed to providing safe drinking water through individual household tap connections by 2024 to all households in rural India. This scheme significantly covers the Indian SDG Target 6.1 dedicated to providing access to safe and reliable drinking water source for everyone. Likewise, the other prominent scheme of *Swachh Bharat Abhiyan* (Clean India Mission) demonstrated success by providing access to toilet facilities in the rural households and achieving the target of Open Defecation Free (ODF) in all the districts. This scheme has been further divided into two parts as *Swachh Bharat Mission (Gramin)* and *Swachh Bharat Mission (Urban)* dedicated to improve sanitation and hygiene in the rural and urban localities respectively. It aims to accomplish SDG Target 6.2 through constructing toilets and waste management. It is pertinent to understand these schemes and how they brought changes to the lives of the poor and marginalized people.

Jal Jeevan Mission (National Water Mission)

The Department of Drinking Water and Sanitation is the nodal body under the Ministry of *Jal Shakti* (Ministry of Water Power) to manage drinking water and sanitation related issues in rural India. Launched in 2009, the National Rural Drinking Water Program (NRDWP) was restructured as a prominent scheme of 2019, *Jal Jeevan Mission* (National Water Mission) that aims to provide Functional Household Tap Connection (FHTC) to every household by 2024. The Mission

facilitates the collective goal of *Har Ghar Jal* (Providing Water to every household). It is committed to ensure in-village water supply infrastructure, reliable and sustainable water source, transfer of water, technological intervention for water treatment, grey water management, and capacity building of various stakeholders. The scheme undertakes community approach to water and aims to make water everyone's priority. It ensures awareness, education, and communication among the masses (Ministry of Jal Shakti).

At the start of the Mission, only 17% of the rural household had access to tap water supply. Over the last 2.5 years when the spread of COVID-19 disease followed by the restrictions and lockdown caused due to it imposed huge challenge, yet the Government made speedy efforts to increase the coverage of the people under the scheme. Consequently, 43.4% of the total rural household are having piped water supply to their homes at present. It is provided that in total 1,18,812 villages and 81 districts have 100% tap water connections. By providing assured tap water supply to all rural households till 2024, India will achieve its commitments under SDG-6 much before 2030 (Ministry of Jal Shakti, 2021).

Swachh Bharat Abhiyan (Clean India Mission)

'Swachh Bharat Abhiyan' (Clean India Mission) is a flagship scheme of the Government of India dedicated to improve sanitation. The Prime Minister of India launched the scheme on the birth anniversary of great leader Mohandas Karamchand Gandhi on October 2, 2014. The scheme was mandated as a nation-wide campaign for the elimination of open-defecation through construction of house-hold and community-hold toilets, mass scale behavioral changes, and establishing monitoring mechanisms for toilet construction.

On October 2, 2019, all the Indian villages, Gram Panchayats, Districts, States, and Union Territories declared themselves as "open-defecation free" (ODF) with the construction of 100 million toilets in rural parts of the country. The Mission has now entered into its second phase, that is, ODF-Plus, to ensure the continuity of ODF behaviors and safe solid and liquid waste management facilities for all without leaving anyone behind.

Both the schemes launched by the Government of India are tremendously improving the needs of the people for safe and accessible water and sanitation. With each passing day, they are achieving new heights and taking India closer to achieve its Goal 6 before 2030. These government initiatives have remarkably uplifted the lifestyle, health and social challenges of the rural people residing in Indian villages. The *Swachh Bharat* initiative not only helped in improving sanitation practices, however also led positive impacts on the environment. It addressed another burning issue of garbage disposal. Moreover, it has brought respect to the individuals involved in cleaning and waste management processes (PBNS, 2022).

State Participation and Good Practices

Along with the Central Government schemes, States and sub-national governments are the key agents to implement these goals on ground. One of the features of SBA was that it provided

autonomy and flexibility to the State government to implement these schemes as per their suitability. For instance, the Chhattisgarh State, decided to pursue community-based approach instead of subsidy-driven approach for implementing Swachh Bharat Mission, allowing local communities to take charge on field for the construction of toilets and promote sanitation measures. Notably, the Government of India has incentivizes the toilet building by providing Rs. 12000 (157 USD) to every household for its construction. It transfers the incentive amount to the Panchayat, that is the local village government, to further provide it to the beneficiaries. Here the local government has the flexibility on the preferred strategy of incentive allocation. They may allocate the entire amount to the poor household, half amount to the middle-income household, while no amount to the rich and efficient families. Highlighting this flexibility, the CEO of Raigarh Zila Parishad, a district-level officer in Chhattisgarh State, mentioned that they have created a district-level team to scale up sanitation campaign and when it creates the demand for building toilets, the officials encourage communities to construct toilets using own money and resources. This approach brings a sense of responsibility and ownership among the natives resulting in higher usage of toilets. Once the village is declared as ODF, only then the officials transfer the subsidy amount to the local population. Additionally, the State included another condition that the amount should be provided for using the toilets and not constructing it. For this purpose, after the construction of the toilets the communities should use them. There will be inspection by the State and District level teams in the three months, followed by another inspection from the State level team in six months. Only then the incentive amount can be provided to the beneficiary household. In this manner, the State and District authorities have replaced the criteria of incentive amount from toilet construction to the actual use of the toilets. Through this change, they not only established a monitoring mechanism however also attempted to change behavior of the people by including toilets usage in their habit.

These schemes have not only ended the practice of ODF but also empowered local and marginalized people. One of the female residents from Tipakhol, one of the first villages in Chhattisgarh State to be declared as ODF, described that they constructed their toilets themselves using their own money and locally available resources like bamboo and stones (Somya, 2016). Importantly, before the scheme women did not participates in the village-level meetings, however the situation has changed since now they are playing active role in the village development. Due to these approaches, the local people themselves became the brand ambassador to spread awareness and self-capable to help toilet construction in the adjacent villages. The State further adopted strategies like restraining those who do not have toilets in their household to contest election. Also, it restricts such people from availing any benefits from the government.

The innovative practices adopted in the Chhattisgarh State highlight their sincerity and commitments towards achieving ODF status and adequate sanitation and hygiene. First of all, they placed people as a central to their action plan. The State had a concept of 'Navratna' meaning nine gems, indicating nine prominent people from the community leading the sanitation movement. In addition, India has *Gram Sabha* (a general assembly of all the people from village) in every village as a democratic setup at the lowest level. These *Gram Sabha* have constituted vigilance committees composed of women and children, known as '*Swachhta Commandoes*'

(Cleanliness Commandoes). The function of these Commandoes is to look around during morning and evening time that the ODF practices are being followed by the communities. They also maintain a file known as 'Swachhta Panji' (Cleanliness Register) to record the discussions on cleanliness by the *Gram Panchayat* (Village Council). Chhattisgarh is among the most backward States of India having 85% of its population practicing open defecation. However, their commitment and implementation strategies are praiseworthy and inspiring for other States and countries.

Likewise, States have demonstrated several effective practices towards securing water for its population. Considering the Indian state of Gujarat that is primarily consists of water scarce regions have demonstrated remarkable outcomes towards achieving Target 6.1. Several strategies have satisfied the needs of the local population and provided them water supplies. Inter-basin water transfer from the river Narmada project waters to the deprived regions of Gujarat, including Kutch, Saurashtra and North Gujarat have proved significant. Shifting water supply from ground water based to surface water based is yet another strategic move to help the local population. For providing improved sources of water and PWS, a network of pipelines has been laid along the State that ensures double security of these water sources. Lastly, the involvement of local population and community participation by constituting *Pani Samitis* (Village Water and Sanitation Committees) work as local public water utilities and further achieve Target 6.b. These committees being composed of 50% men and 50% women acts as change agents who bring drinking water security in their villages. Touching upon the notion of equity, inclusiveness and mutual trust, these welfare policies have open avenues for long-term engagements with the local population.

Conclusions

Being the second-most populated country, India balances its huge water demand with limited resources. It sets an inspiring example for water and sanitation management through a catena of judicial decisions on the subject-matter and public participation on grass-root level. Independent studies notes that government plans and policies have contributed to an increased quality of life of the population. Amid prevailing economic and environmental stress, India remained committed to the spirit of leaving no one behind by improving safe drinking water and access to toilet facilities, particularly for women and rural communities. In this context, the research paper highlights Indian experiences of securing SDG 6 and outline crucial lessons from its implemented policies. The Indian localization approach demonstrates an impressive strategic model on SDGs. Application of the Indian SDG localized model secures enormous water demands, improves infrastructure, creates opportunities, and strengthens democratic ties. Further, the adoption of two of its prominent schemes, Jal Jeevan Mission and Swachh Bharat Abhiyan has significantly fulfilled the water and sanitation related needs of local communities. Provided that a large population belongs to poor and under-developed region. Indian experiences on achieving SDGs will play a substantial role in setting examples for other countries. Moreover, it suggests inclusive and structured water management policies beneficial for applying SDG 6 in other parts of the world.

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Renewable Energy for Rural Electrification of Sub-Saharan Africa: Why It Matters (SDG7)

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Abstract

For over five decades, electricity grids in many Sub-Saharan African countries have been limited to urban areas, leaving the rural communities with no electricity. This is why it matters to have a paradigm shift from centralized urban grids to standalone micro-grids powered by renewable resources from rural localities. This paper describes an approach to designing such standalone systems. The approach, which is based on the concept of Renewable Energy Map, has been applied to the South-West Region of Cameroon. The Map, which identifies the locations of Renewable Resources and quantifies the electricity generation potential of each resource, has been used to design a Rural Electrification Master Plan for 480 villages of the South-West Region. As part of the Master Plan, 54 Renewable Power Generators have been designed. These include 18 Biomass Generators powered by Empty-Palm-Fruit Bunches, 16 Run-of-River Mini-Hydro Power Generators and 12 standalone Solar Generators. The project is the fruit of a partnership between the University of Buea and the thirty-one Councils (Local Governments) of the South-West Region of Cameroon.

Keywords: Renewable Energy Map; Rural Electrification Master Plan; Empty Palm Fruit Bunches; Run-of-river Scheme

Introduction

95% of people with no access to electricity live in Sub-Saharan Africa and Asia, and 80% of these energy-deprived people live in the rural areas (IEA, 2017). For these rural inhabitants, the Sustainable Development Goal Number 7, which requires all citizens of the world to have access to affordable, reliable and sustainable energy, remains an unattainable luxury. According to 2014 World Bank Statistics, rural access to electricity is as low as 0.4% in the Democratic Republic of Congo, 3.09% in Central African Republic and 4.53% in Chad. This is why it matters to develop a sustainable rural electrification strategy for Sub-Saharan Africa.

Rural communities, which are the most affected by poverty, in the economic sense, are further affected by Energy Poverty, in the context of access to energy. According to the 2021 Energy Progress Report, about 759 million people in the world still lack access to electricity and only 46% of the population in Sub-Saharan Africa has access to electrical energy (IEA et al.,2017).

While technology and industrialization are growing at a fast pace, the means of providing clean electrical energy to the world's population, at a relatively low cost, remains a challenging task (Rehman,2021).

If the problem of rural electrification is not addressed, the African Union Agenda 2063 vision of a prosperous Africa in which citizens drive their own development will remain a hollow dream. The African Union has long recognized the fact that Agenda 2063 cannot be achieved without developments in Science, Technology and Innovation. This is why the STISA-2024 (Science, Technology and Innovation Strategy for Africa) was designed. STISA-2024 has five priory areas (Clusters), one of which is Energy. This is why it matters to solve the problem of rural electrification in Sub-Saharan Africa, to make a contribution to the realization of both Agenda 2063 and STISA-2024.

The project reported in this paper is based on the use of a Renewable Energy Map in developing a sustainable rural electrification master plan for four hundred and eighty (480) villages in thirtyone Councils (Local Governments) of the South-West region of Cameroon. The project provides a model which can be leveraged and replicated in other Sub-Saharan African countries, especially countries of the Equatorial Rain Forest which are endowed with renewable resources similar to those in Cameroon.

The replication of this rural electrification model in many Sub-Saharan African countries will impact several Sustainable Development Goals (SDGs), since SDG7 is the epicenter of the system of SDGs. Energy impacts every economic or developmental activity. The Sustainable Development Goal Number 7 is at the epicenter of all Sustainable Development Goals, since it impacts many other SDGs. This dependence of other SDGs on energy is illustrated in figure 1.



Figure 1: Energy as the epicenter of Sustainable Development Goals

Energy directly or indirectly facilitates the attainment of at least 8 other Sustainable Development Goals (SDGs), including SDG 1, to end poverty, SDG 3, to ensure healthy lives and promote wellbeing; SDG 4, access to quality education; SDG 8, to promote sustained, inclusive and sustainable economic growth; SDG 9, to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; SDG 13, to combat climate change; SDG 15, to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt biodiversity loss.

The availability of electricity to both rural and urban populations provides a lever to poverty alleviation, improves the well-being of the population, facilitates inclusive economic growth through the creation of enterprises, facilitates industrialization and fosters innovation. It also combats climate change by reducing the pressure on forest exploitation to provide firewood for rural populations, combats desertification and halts biodiversity loss which is a consequence of the depletion of forests resulting in the loss of the natural habitat of wildlife. Energy impacts most of the Sustainable Development Goals. This is why it matters to solve the problem of rural electrification in Sub-Saharan Africa.

The authors' research shows that absence of electricity is the epicenter of the underdevelopment matrix of Sub-Saharan Africa, as illustrated in figure 2. The lack of electricity is deadweight on the development of Sub-Saharan Africa. The replication of this model of rural electrification in other countries of the region will remove this deadweight and reverse the phenomena highlighted in figure 2.



Figure 2: Lack of Energy and the Underdevelopment Matrix of Sub-Saharan Africa (From the Author's Research and Analysis)

Why It Matters

The national grids in many Sub-Saharan African countries distribute electricity from hydro-electric power stations. In Cameroon, for example, there are three hydro-electric stations: Edea, Songloulou and Lagdo. Edea and Songloulou supply the more populous southern part of the country while Lagdo supplies the north. This dependence on hydro-electric stations built many decades ago is the same in many countries.

The electricity grids supplied by these hydro-electric stations are limited to urban centers for two main reasons:

- The power output of the hydro-electric stations is not sufficient to meet the needs of the urban and rural populations
- The rural areas cover wide geographical areas and huge power losses would be incurred if the grids were extended to these localities

These two factors have been the greatest impediment to the expansion of the national grids to the rural areas. For over five decades, many Sub-Saharan African countries have not overcome the problem of grid limitation. One solution is to build more hydro-electric stations but very few new stations have been built. The situation is further compounded by demographic factors such as the rapid population increase, both in the urban and rural areas.

It is now clear that the paradigm of centralized electricity distribution from hydro-electric power stations does not provide a solution to the problem of rural electrification. This approach to electricity distribution has not solved the problem of rural electrification for over five decades and from all indications, it will not solve the problem even in the next five decades.

This is why it matters to have a paradigm shift to decentralized standalone micro-grids powered by renewable resources from many localities.

Methodology

A four-step methodology is used in the project:

- Development of the Renewable Energy Map of the South-West Region
- Design of a Power Generation Schedule for 480 villages which lack electricity in the region
- Design of Power Generators to supply the villages
- Development of Partnerships for Project Consolidation, Implementation and Replication

Development of the Renewable Energy Map of the South-West Region of Cameroon

The concept of Renewable Energy Map is used to identify the locations of renewable resources in a specified geographical area and to quantify the electricity generation potential and sustainability of each of the resources.

The potential of Renewable Energy in providing electricity to all inhabitants of rural communities has long been recognized by many researchers (Rehman, 2021) but the slow pace of tapping this great potential is due to the absence of strategies which address sustainability of resources, high initial cost and resource mobilization. The concept of Renewable Energy Map is a model of sustainability modeling and a tool for the design of low-cost electrification systems.

The application of the concept to the South-West Region of Cameroon revealed an abundance of four types of renewable resources:

• Biomass from Empty Palm Fruit Bunches: Palm oil is produced on a massive scale by two big Agro-Industries located in the South-West Region of Cameroon: Cameroon Development Corporation (C.D.C.) and PAMOL. The Empty Palm Fruit Bunches, which

are residue from palm oil production, are mainly dumped as organic waste. In addition to these two agro-industries, thousands of small-scale farmers also produce palm oil and dump tons of Empty Palm Fruit Bunches.

- Fast Flowing Streams and Rivers: The South-West Region is endowed with 16 fast flowing streams and rivers with great hydro potential.
- Waterfalls: The region also has 8 waterfalls with significant hydraulic head.
- Solar Energy: There is an abundance of solar energy everywhere in the region, but this
 resource is assigned the lowest priority in the Rural Electrification Master Plan because of
 the high cost of community-scale solar systems, compared to other options. Solar Energy
 is used only in villages which do not have any of the other resources (Empty Palm Fruit
 Bunches, Fast Flowing streams or rivers, Waterfalls).

Power Generation Schedule for 480 Villages

From the analysis of the data provided by the Renewable Energy Map, a total of 54 power generators are required to supply 480 villages which are without electricity in the region. These include 18 Empty-Palm-Fruit-Bunch Biomass generators, 16 run-of-river mini-hydro power generators driven by fast flowing streams or rivers, 8 Mini-hydro power generators driven by waterfalls and 12 standalone solar power generators. The allocation of these generators to the villages is shown in table 1.

The data used in constructing the Renewable Energy Map was collected by a team of Engineers from the Faculty of Engineering and Technology of the University of Buea. The data acquisition process was facilitated by Project Liaison Officers from the 31 Councils (Local Governments) of the South-West Region of Cameroon. The Project Liaison Officers were designated by the Mayors of the Councils (1 per Council). The Liaison Officers selected Local Guides from the communities to show the team of Engineers the locations of renewable resources such as waterfalls, dumps of empty-palm-fruit bunches, fast-flowing streams and rivers.

The Engineers then measured the Hydraulic Heads of the waterfalls and Flow rates of the fastflowing streams and rivers, in order to determine their mini-hydro potentials. From the dumps of empty-palm-fruit bunches in each location, the Engineers estimated monthly averages of this resource in order to quantify the electricity generation potential and sustainability. The Engineers also carried out energy audits of the villages to determine the number of villages which can be supplied from each of the power generators.

The information in table 1 is a synthesis of the data collected by the team of Engineers. The study shows that twelve villages are not located near fast-flowing streams or rivers and do not produce palm oil. The only sustainable resource for the 12 villages is solar energy.

Table	1:	Power	Generation	Schedule	for the	Villages
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No.	Type of Generator	Number of Generators	Number of Villages
1	Empty-Palm-Fruit-Bunch Biomass	18	206
2	Run-of-river Mini-hydro driven by fast flowing streams or rivers	16	172
3	Waterfall-driven Mini-hydro	8	90
4	Solar	12	12
Total		54	480

Design of Power Generators to Supply the Villages

The objective is to design power generators to facilitate the construction of 54 turn-key power stations. Apart from the solar stations which are autonomous systems in each of the 12 villages, each of the other generators is designed to supply a group of villages.

Design of the Empty-Palm-Fruit-Bunch Biomass Generators

Each of the 18 biomass power generators was designed to incorporate 3 subsystems:

- Pelletizer
- Power Generator
- Micro-grid

Design of the Pelletizers

Pelletization reduces the Empty-Palm-Fruit-Bunch biomass to pellets which are suitable for combustion in the power generation.

After the collection of the Empty Palm Fruit Bunches, unwanted impurities are manually removed and the sizes of the bunches are reduced to facilitate drying. The drying is done to reduce the moisture content. After the drying process, the pellets are then produced using the pelletization machine. Because of the heat involved during this process, they are cooled and then stored for usage. These final pellets are the fuel which is fed to the generator.

Cameroon is endowed with a huge potential of palm biomass. The country produces an estimated 300,000 tons/year (Rosalien Jezeer and Nick Pasiecznik, 2019).

Palm trees are rich in biomass and produce seven different types of biomass products (Onoja et al., 2018). Only one of these biomass products, the Empty Palm Fruit Bunches (**EPFB**), is used

in this project. The EPFB accounts for about 23% of the weight of fresh cones of palm nuts. The fresh cones and residual Empty Palm Fruit Bunches are shown in figure 3.



Figure 3: Oil Palm Cones and Residual Empty Palm Fruit Bunches

Pelletization reduces the Empty Palm Fruit Bunches into pellets which are suitable for combustion in the power generator. Figure 4 shows the pelletization process and figure 5 shows the Pellets.



Figure 4: EPFB Pellet Making Process



Figure 5: EPFB Pellets

Design of the Power Generators

Conversion of large quantities of pelletized Empty Palm Fruit Bunches to electricity is done by combustion of the pellets in a furnace, to generate high-pressure steam. The operational principle is shown in figure 6.

When the pellets are fed into the combustor, in the presence of excess air, they are burnt in the combustor to produce heat. Water is then pumped from the condenser to the combustor using a high-pressure pump transforming it into high pressure steam which rotates the steam turbine blades. The turbine is mechanically coupled to a generator through a high-speed rotating shaft. When the shaft rotates, it causes the rotor of the generator to rotate, cutting the flux of the stator and generating electricity. The hot air from the combustor goes through the cyclone where tar is separated from the air. The solid slag is recycled back into the combustor for combustion. The solid free air then runs through a scrubber where it is purified by removing toxic gases and dust, making the air environmentally friendly and ready for discharge into the atmosphere through the chimney.

One of the smallest generators was designed to supply a village of 200 households requiring 11 KW of power. The quantity of pellets required to produce this power, for a plant efficiency of 35%, operating 24 hours a day was calculated from equation 1 (Olisa & Kotingo, 2014).

$$P = \frac{MQe}{t}$$

(1)

Where P is the electrical power (kW), M is the quantity of pellets in (kg), Q is the net heating value of the pellets in (MJ/kg), t is the operational time (hours), and e is the plant efficiency.



Figure 6: Operational Principle of the Biomass Power Generator

Design of the Micro-grid

Each of the 18 Empty-Palm-Fruit-Bunch biomass generators was sized, based on estimates of the biomass available to feed the generators. The sizing provided an estimate of power output and this was used to determine the number of villages which could be supplied by each generator. A micro-grid was then designed to transport power to the target villages. 14 of the generators were sized to supply several villages. Only 4 were sized to supply only one village each.

Design of Run-of-river Mini-hydro Generators Driven by Fast Flowing Streams or Rivers

All of the 16 Mini-hydro generators, driven by fast flowing streams and rivers, were designed as run-of-river diversion schemes. These are low-cost schemes since they do not incorporate reservoirs or dams. The scheme is shown in figure 7.



Figure 7: Run-of-River Diversion Scheme

Water is diverted from the main stream or river to create a hydraulic head which is passed through the penstock with high energy. The pressurized water in the penstock rotates the turbine which spins the shaft coupled to the generator. The subsystems of the scheme include the intake from the river or stream, Desilting tank, Power Canal (headrace), Forebay, Penstock, Power House and Tailrace Canal.

The nominal power of the hydro system P_{hyd} is the power produced by the hydro turbine. It is a function of Hydraulic Head and Flow Rate. The computation includes the efficiency of the hydro turbine but not the pipe head loss. The nominal hydro power is given by equation 2.

$$P_{hyd.nom} = \frac{\eta_{hyd} \cdot \rho_{water} \cdot g \cdot h \cdot \mathcal{G}_{design}^{\mathsf{L}}}{1,000,000W / MW}$$

Where:

 $P_{hyd,nom}$ is the nominal hydro power output of the hydro turbine (MW)

(2)

 h_{hyd} is the hydro turbine efficiency (%)

 ρ_{water} is the density of water (1000kg/m³)

g is the acceleration due to gravity (9.81 m/s²)

 h_{net} is the effective water head (10m)

 Q_{design} is the hydro turbine flow rate (15m³/s and 20m³/s)

The application of equation 1 to one of the diversion schemes with a Head of 10m and Flow rate of 15m³/s resulted in a numerical value of 1.1772 MW, obtained from:

$$P_{hyd.nom} = \frac{0.8 \times 1000 \times 9.81 \times 10 \times 15}{1,000,000} = 1.1772MW$$

The application to a second scheme with a Head of 10m and flow rate of 20m³/s resulted in a numerical value of 1.596 MW, obtained from:

$$P_{hyd.nom} = \frac{0.8 \times 1000 \times 9.81 \times 10 \times 20}{1,000,000} = 1.5696MW$$

The calculated P_{hyd} values for each of the 18 Mini-hydro Power Generators were used to determine the number of villages which could be connected to the micro-grids transporting power from the generator to the villages.

Design of Waterfall-driven Mini-hydro Power Generators

All of the 8 Waterfall-driven Mini-Hydro Power Generators were designed as Diversion Schemes, but the diversions were from the base of each of the waterfalls (ground level). This design option maximizes the Hydraulic Head impacting the turbines. The diversions are very short, compared with run-of-river schemes.

Apart from this structural difference, the technology used in Waterfall-driven Mini-Hydro plants is exactly the same as that used in the run-of-river plants (Figure 7).

A two-step methodology was used for each of the Waterfall-driven mini-hydro power plants:

- Dimensioning and configuration of the Hydraulic System
- MATLAB Simulation for design of system parameters and testing of system stability and robustness to faults

Dimensioning and Configuration of the Hydraulic System

Table 2 shows the design parameters for one of the waterfalls with a Head of 30m and a flow rate of $2m^3/s$.

Intake	Area of intake	1m ²	
	Flowrate	2 m²/s	
	Velocity	2 m/s	
	Width	2m	
Settling Basin	Length	10 m	
	Depth	1.66 m	
Head race	Width	1.33 m	
Forebay	Storage volume	18 m³/m	
	Thrashrack height	1m	
	Length	71m	
	Diameter	0.76m	
Penstock	Thickness	2.47mm	
	Head loss	1.21m	
	Net head	28.79m	
	Turbine type	Francis turbine	
	Nominal speed	500 rpm	
	Turbine dimension (m)	D ₃ =0.65; D ₁ =D ₂ =0.64	
	Generator type	Synchronous	
Turbine-Generator	Generator apparent power	584 kVA	
	Combined efficiency	0.6	
	Generator current	850A	
	Generator frequency	50 Hz	
	Generator poles	12	
	Active power generated	467 kW	
	Capacity factor	0.6	
Transformer	Rating	700 kVA	
	Primary voltage 400 V		
	Secondary voltage	15 kV	
	Number of phases	3	

Table 2 Dimensioning of the Hydraulic System for a Waterfall with a Head of 30m

MATLAB Simulation for Design of System Parameters and Testing of System Stability and Robustness to Faults

The "Powergui" tool in MATLAB was used to automatically calculate the load flows.

A three-phase line-to-ground fault was introduced at 0.3s and removed at 0.4s. The simulated results from the generator, exciter and turbine showed that the response of the system was acceptable. The configuration of the system, obtained from the simulation is shown in table 3.

From the simulation, five graphs were plotted: the turbine speed characteristics; the generator output voltage characteristics; the generator excitation voltage characteristics; field current characteristics; and the stator current were all plotted with respect to time.

The plant's ability to overcome faults rapidly and effectively was tested by the introduction of a fault. The fault type used was the three-phase line-to-ground fault, which is the most common in practice. The fault was initiated at 0.3s and lasted for a period of 0.1s. The following observations were made:

- During the duration of the fault, the generated output voltage V_a dropped significantly from the nominal 1 pu to 0.15pu where stabilised for the duration of the fault.
- The stator current I_{abc} increased from 1pu to 12 pu and even after the fault was cleared at 0.4s, the current transients lasted for approximately 0.1s more.
- The excitation voltage, V_f increased from its initial values of 1 pu to 3.5pu during the fault and took 0.3s to return to the initial state.
- The machine speed dropped from the initial value of 1 pu to 0.885 pu and then rose to 1.118 pu at the start of the fault. The system took approximately 0.3s to attain equilibrium.

 Table 3: System Configuration generated from the MATLAB Simulation

System Parameter	Value of Parameter
Power and Voltage Rating of Synchronous Machine	584 kVA 400V
Nominal Power and Root-mean-Square Voltage	584 kVA 400 V rms
Bus Type	P & V generator
Voltage of first Phase of Generator, Uan	400 Vrms [1 pu] -30.15°
Voltage of second Phase of Generator, Uab	400 Vrms [1 pu] -0.15°
Voltage of third Phase of Generator, Ubc	400 Vrms [1 pu] -120.15°
Current of first phase of Generator, la	675.77 Arms [0.8017 pu] -34.24°
Current of second phase of Generator, Ib	675.77 Arms [0.8017 pu] -154.24°
Current of third phase of Generator, Ic	675.78 Arms [0.8017 pu] 85.76°

Power	4.67e+05 W [0.7997 pu]		
Mechanical Power, Pmec	4.7282e+05 W [0.8096		
	pu]		
Torque	3010 N.m [0.8096 pu]		
Excitation Voltage, Vf:	2.3892 pu		

However, there was an abnormality in the generator excitation response graph. From the literature review, it was expected that excitation voltage would be constant (nominal value) at the start, then increase during the fault and then return to normal after the fault. The observed response was different. This was a consequence of the excitation signal from Simulink.

The response of the system to the simulated fault was consistent with the theoretical prediction. The voltage induced in a machine is a function of both the Flux linking the machine and the synchronous speed of the machine. Consequently, the increase in the excitation voltage during the fault increases the induced flux.

The machine speed which was expected to increase by the same order of magnitude as the excitation voltage, only increased by around 0.012 pu. This is explained by the fact that the speed is limited by the maximum flow rate which is only 2m³/s. The Governor controls the position of the Wicket Gates, but the flow rate depends on the availability of flowing water. Furthermore, after the fault was removed, at 0.4s, the stator current and speed both oscillated down to their initial values before the fault with the latter oscillating for about 0.4s (0.3-0.7) just around the pre-set condition and took longer to stabilize with a possible explanation being the rate of opening or closing of the wicket gates by the governor.

Design of Solar Power Generators

The solar power generators for the 12 villages shown on table 1 were all designed as standalone (off-grid) systems. Each system was designed in a three-step process which included:

- Energy Audit of the households in the village
- Sizing of the battery bank
- Sizing of the PV Array, Charge Controller and Inverter

The design process for one of the villages with 200 households is presented.

Energy Audit

The Energy Audit for the village with 200 households is shown in table 4.

Table 4: Energy Audit of a Village with 200 households

Average Daily Energy Consumption per household	1.315 KWh
Daily Consumption for the community of 200 households	263 KWh
Power required to supply the energy	10.96 KW

Sizing of the Battery Bank

Considering a 240V system, then the Ah rating (Q) of the battery will be given by equation (3).

$$Q = \frac{Eac}{240} = \frac{292000}{240} = 1218 \,Ah \tag{3}$$

This calculation is done considering one day of autonomy. If a 70% **Depth of Discharge** (**DOD**) is considered (Jäger et al., 2014), then the new system battery capacity becomes

$$Q = 1218 \div 0.7 = 1740 \,Ah. \tag{4}$$

Using 200 Ah, 12V batteries, the total number of batteries (n_{Bat}) required are computed from equation 5.

$$n_{Bat} = 1740 \div 200 = 9 \tag{5}$$

We obtained 9 batteries in parallel and 20 batteries to be connected in series to give 240V as the system voltage since each battery outputs 12V. Therefore the total number of batteries (N_{Bat}) is

$$N_{Bat} = 9 \times 20 = 180$$
 (6)

The sizing of the battery bank is summarized in table 5.

Table 5: Sizing of the Battery Bank

Power Rating of Battery	1740 Ah
Number of batteries	180
Number of rows of batteries	9
Number of batteries connected in series in each row	20

Sizing of the PV Array, Charge Controller and Inverter

Considering a battery efficiency of 90%, 5% manufacturer's tolerance and 3% cable losses [5], then the PV array current (I_{PV}) requirement is given by equation (7).

$$I_{PV}(Ah) = 1740 \div 0.9 \div 0.97 = 1993Ah \tag{7}$$

(10)

Considering the worst months in the wet season with daily peak sun hours of 4.5 hours, then the current requirement of the PV array will be

$$I_{PV}(A) = 1993 \div 4.5 = 1136.38 \div 4.5 = 443A \tag{8}$$

Using the PV module of table 4, the current can be modified to

$$I_{PV \ module} = 9.16 \times 0.95 \times 0.95 = 8.27A$$

Therefore the number of modules $(n_{PV \ Module})$ to be connected in parallel is

$$n_{PV \ Module} = 443 \div 8.27 = 54 \tag{8}$$

The number of modules to be connected in series is 10, to give an input voltage of 240V to the charge controller since each module has a nominal voltage of 24V.

The total number of modules N_{PV_Module}

$$N_{PV \ Module} = 54 \times 10 = 540 \tag{9}$$

Subsystem	Characteristics	Value
	Technology	Silicon-Crystalline
	Rated Power	300 Watts
	Nominal Voltage	30.2 Volts
	Nominal Current	9.6 Amperes
PV Array		
	Short Circuit Current	9.6 Amperes
	Open Circuit Voltage	40.1 Volts
	Number of Panels connected in	54
	parallel	
	Number of modules connected	10
	in series	
	Total Number of Panels	540
Charge	Rating	100 A
Controller	Charge Controller Current	554 A
Inverter	Rating	15 KW

Table 6: Sizing of the PV Array, Charge Controller and Inverter

The charge controller current ($I_{Controller}$) is evaluated by equation (10)

$$I_{Controller} = 1.25 \times 443 = 554A.$$

The factor 1.25 (Ammar Alkhalidi, 2017) provides a margin of safety which protects the charge controller. Using a 100A charge controller, 6 charge controllers are needed.

The Inverter was also sized to withstand the load demand. Considering the 10.958 kW which is the required output power to produce energy for 24 hours, the inverter size is calculated from equation (11).

 $P_{Inverter} = 11 \times 1.25 = 13.75 KW$

(11)

This implies that an inverter rated at 15kW is suitable for the system.

Development of Partnerships for Project Consolidation, Implementation and Replication

Partnership for Project Implementation

The project has now reached the construction phase. According to the Memorandum of Understanding between the University of Buea and the thirty-one Councils of the South-West Region of Cameroon, the responsibility for the construction of the Rural Electrification Systems is jointly shared by the thirty-one Councils and the Faculty of Engineering and Technology of the University of Buea.

The role of the thirty-one Councils is resource mobilization. The Councils are presently sourcing for financial resources for the construction of the 54 Power Plants. Each Council will finance the construction of the plants within its Council area.

The role of the Faculty of Engineering and Technology is the construction of the plants. In return, the Faculty will be paid consultancy fees by the Councils. An agreement has already been reached on the amount of fees to be paid by each Council. This will significantly empower the Faculty to embark on other outreach activities. The resource mobilization by each Council will raise enough funds to cover both the procurement of equipment and payment of consultancy fees to the Faculty.

Development of a Triple Helix Partnership for Extension of the Project to Other Parts of Cameroon

Many Mayors from Councils of other Regions of Cameroon have expressed interest in the Rural Electrification Project between the University of Buea and the thirty-one Councils of the South-West Region. This has caused the University of Buea to lobby several Government Line Ministries as well as Electricity Companies operating in Cameroon, to initiate a Triple Helix Partnership between Universities, Government and Power Industries. The purpose of the partnership is to provide a framework for extending the Rural Electrification Project to the other Regions of Cameroon. The Government Line Ministries solicited for this partnership include the Ministry of Water and Energy; Ministry of Higher Education; Ministry of Scientific Research and Innovation; Ministry of Industrial Development; Ministry of Finance; Ministry of Economy and Plan.

The broad outline of the Partnership has been elaborated. One University will be selected from each Region of Cameroon to develop the Renewable Energy Map of the Region and the Rural Electrification Master Plan for the Region. The University of Buea will coordinate and supervise the work of all the Universities involved in the project.

The Electricity companies will build the Power Plants which are designed by the Universities. The Central Government will give tax exemption to the Electricity Companies for a period of five years, to enable them devote their resources to investment in the power plants.

Partnerships for Capacity Building and Replication of the Project in other Countries of Sub-Saharan Africa

The University of Buea has developed partnerships with seven African Universities to build capacity in Renewable Energy on the African continent. These partnerships are within the framework of two European Union Intra-Africa Mobility Projects, funded in the 2019 round of projects.

One project, MASTET (**M**obility of **A**frican **S**cholars for **T**ransformative **E**ngineering **T**raining), is implemented by a Consortium of five African Universities, including the University of Buea, in Cameroon, Makerere University, in Uganda, Stellenbosch University, in South Africa, Abomey Calavi University, in Benin, and Botswana University of Agriculture and Natural Resources. Twenty-four African Scholars from 20 countries are currently being trained in Masters and PhD programmes offered by the Partner Universities. By the time the MASTET project ends, a total of thirty-four African scholars will have been trained.

The second project, MIRET (Mobility for Innovative Renewable Energy Technologies), is implemented by another Consortium of five Universities, including the University of Buea, Moi University, in Kenya, Makerere University, University of Sfax, in Tunisia and the University of Zambia. Thirty students are currently being trained at the Masters and PhD levels in programmes in the domain of Renewable Energy. By the time the MIRET project ends, a total of forty African scholars will have been trained.

Many of the MASTET and MIRET students are currently doing their research projects on various Rural Electrification thematic areas. This is a concrete strategy to build capacity across Africa. The Partner Universities share their expertise and experience in various Renewable Energy Technologies.

The project reported in this paper is already shared with other Partner Universities and is widely regarded as one of the best practices in the continental rural electrification drive. It can, therefore, be expected that many other countries will leverage and replicate the project.

Results

The results of the project are six-fold:

- i. A Renewable Energy Map of the South-West Region of Cameroon has been developed.
- ii. The Renewable Energy Map has been used to develop a Rural Electrification Master Plan for the Region.
- iii. The Master Plan includes the Design of 54 Power Plants to supply electricity to 480 villages. The Power Plants include 18 Empty-Palm-Fruit-Bunch Biomass Generators; 16 Run-of-River Mini-Hydro Power Stations, driven by fast flowing rivers and streams; 8 Waterfall-driven Mini-Hydro Power plants and 12 Solar Power Plants.
- iv. The Renewable Energy Map provides an innovative model of sustainability management and a tool for low-cost design of rural electrification systems.
- v. The project is an innovative case study which can be leveraged and replicated in other Sub-Saharan African countries to accelerate the attainment of SDG7, in particular, and other energy-dependent SDGs, in general. The replication of the project in other parts of Sub-Saharan Africa will also impact the continental visions of Agenda 2063 and STISA-2024.
- vi. The project is a concrete example of University/Local Government Partnership

The impact of the project will be measured by three indicators:

- The number of power generators built in the South-West Region
- % increase in access to electricity by rural populations of the region
- Number of regions which replicate the project in Cameroon

Conclusions

Five conclusions are drawn from the project:

- i. Renewable Energy Maps serve a dual purpose as a paradigm for sustainability modelling and a tool for the design of low-cost Rural Electrification Master Plans.
- ii. The application of the paradigm to the South-West Region of Cameroon has facilitated the identification of the renewable resources of the Region and quantification of the electricity generation potential of each of the resources. The Renewable Energy Map of the Region
has revealed an abundance of four types of renewable resources: Empty-Palm-Fruit-Bunch Biomass; Fast Flowing rivers and streams; Waterfalls and Solar Energy

- iii. The Renewable Energy Map developed for the South-West Region of Cameroon has also facilitated the development of a Rural Electrification Master Plan for the Region. One deliverable in the Master Plan is a Power Generation Schedule which assigns 54 Power Generators to 480 villages, based on the renewable resources which are closest to each of the villages.
- iv. The project, which is the fruit of a partnership between the University of Buea and the thirty-one Councils of the South-West Region of Cameroon, is a concrete example of how University/Local Government partnership can be used to positively impact the attainment of SDGs
- v. The project is a concrete case study which can be replicated across Sub-Saharan Africa, to accelerate the attainment of SDG7, in particular, and energy-dependent SDGs, in general.

The project opens several perspectives for further work. These include:

- Construction of the Power Plants by the Faculty of Engineering and Technology of the University of Buea, in collaboration with the thirty-one Councils of the Soth-West Region which are currently involved in the resource mobilization drive.
- Future recruitment of Power Systems Engineers trained by the Faculty of Engineering and Technology to serve as Power Plant Operators in the newly constructed plants.
- Extension of the project to other Regions of Cameroon on the basis of numerous requests from the Mayors of the other Regions
- Operationalising the Triple Helix Partnership between the Cameroon Government, the Universities and the Electricity Companies operating in Cameroon, to provide a framework for extending the project to every Region of Cameroon

Acknowledgements

The authors gratefully acknowledge the support of the thirty-one Mayors of the municipalities of the South-West Region of Cameroon. The resource persons provided by the Mayors facilitated

the development of the Renewable Energy Map. The resource persons accompanied the technical team from the Faculty of Engineering and Technology in the field trips to the forests. Their knowledge of the villages and ecosystems of the Council areas was fundamental to the development of a comprehensive Renewable Energy Map.

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Improvement of the Livelihoods of Rural Populations of Sub-Saharan Africa through Post-harvest and Cook Technologies Powered by Renewable Resources (SDG7)

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Abstract

In this research project, the thermal performance of a low-cost solar box cooker/dryer incorporating booster concentrators with optimum dimensions has been investigated. To achieve this, a double V-trough solar concentrator was designed to concentrate the incident solar irradiance onto the absorber window of the solar box cooker/dryer tray. The introduction of the solar concentrator increased the direct insolation by a factor of 2.1. In order to extend the drying/cooking time further beyond dusk, the effect of the energy storage material (basaltic rocks) was also studied. The solar cooker incorporating the rocks was found to have slightly reduced performance, as shown by the reduction in the first figure of merit F1 from 0.07 Km²W⁻¹ to 0.06 Km²W⁻¹, an effect also predicted by (Verma et al., 2022). Experiments conducted on three system configurations (system with no basaltic rocks; system with 1 Kg of 5.6 mm pellets of basaltic rocks; system with 1 kg of 13 mm pellets of basaltic rocks) revealed that the reduction of performance (F1), due to the use of pellets of basaltic rocks, is independent of pellet size. The project is motivated by the need for low-cost, dual-function, non-intermittent cooker/dryers for use in Sub-Saharan Africa.

Keywords: Solar drying, Solar Cooker, Solar Concentrator, Double V-trough Solar Concentrator, Energy storage Materials

Introduction

Brief Review of Solar Thermal Systems and Operation

Solar Cooking

Most solar cookers currently in use are relatively cheap to operate since no fuel is required. The uptake of these cookers has a major role to play in the fight against rising fuel prices, air pollution as well as slowing down the deforestation and desertification caused by the gathering of firewood for cooking (Abd-Elhady et al., 2020). The solar cooker was first demonstrated by a Swiss Scientist in 1767 (Garg et al., 1998) and continues to attract the interest of Engineers and Scientists the world over. Despite this early discovery and the availability of low cost solar cooker versions, the uptake of solar cooker as a household cooking stove remains low (Otte, 2014, Panwar et al., 2012). Efforts are continuously being made to make solar cookers more user friendly, attractive and practicable for developing and developed countries (Nkhonjera et al.,

2017). In many countries with abundant annual solar radiation, the uptake of solar cookers has been observed to increase (Mendoza et al., 2019). A comparison of solar cookers with other conventional cooking methods reported that, the solar box cookers are the most used among the different types of solar cookers.

Energy requirements for cooking food remains one of the primary factors affecting the total energy consumption and consequently greenhouse gas emission the world over. Solar cooking offers an appropriate and practical solution as an inexpensive, green and renewable energy technology. The solar cooking technology can be divided into three main categories based on the different solar cooker structures: (i) box types, (ii) concentrating types, and (iii) panel types. These three different designs are also classified according to their direct or indirect heat transfer modes and the use of optional equipment for latent heat and sensible heat type thermal storage units. The continuous rise in the level of greenhouse gas emissions and the increase in fuel prices remain the main driving forces behind efforts to seek alternative and to more effectively utilize sources of renewable energy. Apart from cooking, solar cookers could be utilized for warming food, drinks as well as to pasteurize water or milk (Panchal et al., 2018, Rossi et al., 2019). In this regard, solar cookers have been observed to significantly improve energy security as well as reduce the reliance of energy consumption on the traditional fossil fuel based options, which have serious adverse effects on the environment via the greenhouse gases they emit (Wentzel et al., 2007, Al-Soud et al., 2010). In order to effectively collect the solar energy required for the cooking process, a number of different types of solar collectors have been designed, developed and studied.

Solar cookers vary in design type and each of these designs are continually being improved over time. Some of these solar cooker types include: the solar panel cooker, solar parabolic cooker and the solar box cookers.



Figure 35: Types of solar cookers: (a) solar panel cooker; (b) solar parabolic cooker; and (c) solar box cooker(Cuce et al., 2013).

The solar panel cookers have a simple and inexpensive construction. They can be easily folded over and stored or transported in back packs. As a result of this, they are very common among communities. These type of cookers, however, suffer from low cooking power due to the fact that they concentrate sunlight from above only. However, their easy portability and convenience

makes them desirable to people who are continuously on the move. The cooking vessel in the case of a panel cooker is enclosed in a cooking bag (a transparent plastic bag).

The parabolic solar cookers have been very attractive due to their exceptional performances. Solar parabolic cookers have the capability of attaining extremely high temperatures in a very short time interval, and unlike the panel cookers and box solar cookers, they do not need a special cooking vessel. As a result of strong heating capability of parabolic cookers, the cooker can burn food if left unattended for some time because of the concentrated power delivery. A solar parabolic cooker consists of a parabolic reflector with a cooking pot which is located at the focus of the parabolic dish and a stand to support the cooking system. Parabolic solar cookers have concentration ratios as high as 50 and so can achieve high temperatures of up to 400 °C, much higher than temperatures observed in solar box cookers (Fatiha Yettou et al., 2018). The main drawbacks of the parabolic solar cooker are the dependence on solar tracking, a constant attention to prevent the burning of foods and fire out breaks during operation (Al-Soud et al., 2010). This cooker is often used in conjunction with heat storage materials to improve energy availability (Senthil, 2021). It has been through the use of automatic solar trackers in parabolic cookers that water temperatures of 90 °C could be attained easily (Al-Soud et al., 2010).

The solar box cooker is the most attractive to households in terms of cost and simplicity. A simple construction of a box type solar cooker is shown in

Figure 38 below. It is worth noting that each of the components of the box cooker has a significant influence on cooking power and performance. These components remain a subject of research to many researchers. The optimization of these parameters has been the main pathway for the improvement of the system performance. Box type solar cookers have been reported to show slow heat up to maximum temperature, but work well even in low irradiation, intermittent cloud cover, low ambient temperature and in windy conditions (Telkes, 1959). Recently, researchers have focused their attention more especially on the optimization of geometric parameters of solar box cookers since these have been found to have a dominant effect on its performance. In line with this approach, many researchers have been analyzing the effects of booster mirrors on the performance of the box-type solar cookers. Booster mirrors have been reported to have a strong influence on the efficiency of solar collectors via the provision of extra solar radiation (Dang, 1986). It was later found that the performance enhancement using booster mirrors was found to dependent strongly on the choice of the angle of the mirrors (Garg et al., 1988).

Many other researchers have focused on the glazing factor in solar box cookers as a means of performance enhancement (Mirdha et al., 2008, Eckert et al., 1996, Deubener et al., 2009, Akhtar et al., 1999). Common glazing material used in the construction of box-type solar cookers include glass, fibreglass, and acrylics. Single glazed glass and double glazed glass are the most common structures which have been demonstrated to have high transmission. Optimization of the gap between glass panes is also another significant problem since a large air gap may encourage convective heat transfer and result in higher heat loss. Air gaps in the range of 1 - 2 cm have been recommended (Saxena et al., 2011, Eckert et al., 1996, Deubener et al., 2009). The absorber plate inside the cooker emits long wavelength radiation towards the glazing glass, absorption of this radiation by the glass results in the increase in temperature, hence heat loss

from the cooker to the surrounding atmosphere is possible. As a remedy to the energy loss via the glazing glass, Kalogirou proposed the use of transparent insulators for the glazing material (Kalogirou, 2004, Kalogirou, 2003).

The absorber plate at the bottom of the box-type cooker has also been found to have a significant effect on the performance of the solar box cooker. The solar radiation that enters the cooker through the glazing window is absorbed by the absorber plate which is usually painted black to improve its efficiency. An absorber plate is usually characterized by its absorptivity. The higher the absorptivity, the higher the heat energy it will be able to transfer to the food in the cooking vessel (Garg Hp et al., 2004). It has also been demonstrated that fin-like absorber plates (

Figure 36) exhibit better performance by upto 7 % (Harmim et al., 2010).



Figure 36: (a) Schematic of the finned absorber plate; (b) conventional (A) and improved (B) solar box cooker (Harmim et al., 2010).

Solar Drying

One of the most common post-harvest preservation techniques is by drying. Drying of food and fruits during peak seasons has the potential of improving food security throughout the year. Solar drying can be achieved by drying the food products in direct sunlight. This technique is cheap to implement, however, apart from exhibiting a slow rate of drying, it also exposes the food crops to contamination. This results in the need for controlled drying systems for different agricultural products. Most conventional dryers are operated by coal, oil or firewood. Due to the emissions of greenhouse gases by these fuels there is need for alternative controlled drying systems such as solar dryers.

Solar dryers could be classified into two main categories: direct and indirect solar dryers. The direct solar dryer involves directly exposing the material to be dried to the sun. While in the indirect dryer, the material is dried by circulating hot air over it without direct exposure to sunlight. The air circulation is achieved by use of an external fan or natural convection, resulting in active and passive solar dryers respectively (Figure 3).



Figure 37: (a) A passive indirect solar dryer, (b) passive direct dryer(Gupta et al., 1982).

From 3 above, the solar dryers generally come in the form of a hot box, in which fruit, vegetables or other food materials can be dried. It is often made of a rectangular box made from cheap and readily available materials such as plywood, bricks, concretes and aluminium sheets - insulated at the base and sides and covered with a single and double layered transparent glazing material. Solar radiation is transmitted through the glazing surface and absorbed on the blackened interior surfaces of the dryer. Due to the insulation, the internal temperature is much higher than the external temperature. In order to facilitate convection within the dryer, holes are drilled through the base of the dryer to permit fresh air to circulate into the dryer cabinet. Outlet holes are also drilled at the upper parts of the dryer, sides and rear panels and this helps to remove the moisture from the drying chamber. When the temperature inside the dryer increases, hot moist air passes out of the upper apertures by natural convection creating a partial vacuum and creating a drag on the fresh air at the bottom, upwards through the base. This results in a constant flow of air over the drying material, which is placed on perforated trays, on the floor of the dryer, as shown in figure 4.



Figure 38: Components of a typical solar box type cooker (Saxena et al., 2011)

Thermal Energy Storage Materials

Due to the intermittent nature of solar energy, thermal energy heat storage materials form an important part of the construction of solar cookers/dryer systems (Nkhonjera et al., 2017, Buddhi et al., 2003, Anilkumar et al., 2022). In particular, solar cookers without heat storage materials have a major drawback that food can only be cooked during sunshine hours. This means that food which is near completely cooked cannot be cooked to completion once night falls or when there is a sudden change in weather condition such as rain and cloud cover. Thus, the large scale utilization of this form of energy is not possible unless there is effective implementation of an efficient storage technology that can be developed with minimal capital and running costs. The incorporation of phase change materials (PCMs) in solar box cookers as thermal energy storage (TES) media has been found to show significant improvement in the performance of the cooker mainly due to their high energy storage density capability (Mullick et al., 1987, Sharma et al., 2000). However, sensible heat storage materials have been found to be readily available and at minimal cost. Such materials may exist in either liquid or solid form and include materials such as sand, locally available rocks (basalts, granite, bricks, clay, pebbles, concretes, wood and limestone) and water (liquid form). (Muthusivagami et al., 2010), Nkhonjera et al., 2017) have demonstrated that there was no significant difference in cooking power between cookers made with sensible heat storage materials and PCMs. The effectiveness of these storage materials is strongly dependent on their specific heat capacities and densities. Table 1 below shows the thermal properties of some of the aforementioned sensible thermal storage materials. In addition to these, properties, these materials have long term chemical stability and non-toxic.PCM. They are vulnerable to degradation by loss of water or hydration, chemical decomposition or incompatibility with materials of the cooker construction while some can be potentially flammable and explosive in nature, posing a serious safety challenge.

Medium	Density ρ (kgm ⁻³)	Specific heat
		capacity (Jkg ⁻¹ K ⁻¹)
Basalts	3000	840
Granite	2750	890
Sand	2200	712
Bricks	1698	840
Pebbles	2700	880
Concretes	2200	750
Wood	700	2390
Limestone	2500	900
Water	1000	4190
Clav	1458	879

Table 1: Thermal Properties of some Common Heat Storage Materials

Health and Economic Benefits of Solar Cookers/Dryers

Apart from the enormous environmental benefits that solar energy cookers offer, they also offer economic, health and productivity benefits to the end users (Achudume, 2009, Heltberg, 2004, Pattanayak et al., 2009, Nandwani, 1996). Households using solar cookers/dryers are expected to make savings on cooking fuel as well as reduce their dependency on wood. It has been estimated that up to 36% savings can be made (Farhar, 1998). It is believed that solar cookers will increase fuel security amongst underprivileged households (Wentzel and Pouris, 2007). Despite these benefits, the penetration of solar cookers as an alternative cooking method depends strongly on the cost of the system. Thus, the vulgarisation of solar cookers in any community depends strongly on the cost of the solar cooker system compared to the available alternative solid fuels (Otte, 2013).

As an alternative to cooking with biomass, a common fuel in developing countries, a solar cooker/dryer presents itself as a healthy alternative (Matinga, 2010, Schlag et al., 2008). Health hazards related to biomass such as firewood include the production of smoke and trekking over long distances to gather firewood. Furthermore, solar cooker/dryers improve energy security, leading to improvement in overall welfare (De Lange et al., 2002, Clancy, 2002, Bates et al., 2005). Exposure to smoke pollutants has the potential to cause serious respiratory damage and cancer. Transporting firewood by head, a common practice in developing countries can lead to physical injuries and (Sovacool, 2012, Wentzel and Pouris, 2007).

Purpose

Solar cookers can serve three important purposes: reduction in domestic cooking costs by decreasing the need for purchase or collection of fuel especially done by women; reduction in postharvest losses hence aiding in value addition and food processing activities such as drying, blanching, pasteurization, boiling, stewing, frying and conservation of fuels for other uses, such as fertilizer in the case of dung, forest protection and erosion control in the saving of wood and charcoal. A major challenge to delivering on solar based stoves and technologies is using locally available materials and capacity building programmes to fabricate and implement these technologies and innovations at grass root level while assuring quality, cross-learning, resource sharing and rationalized use. While efficient harnessing of solar energy can mitigate many of SSA's energy problems, this paper focuses on exploitation of solar energy for cooking using solar cookers.

The Sustainable Development Goals (SDGs) are designed to improve on the welfare of the world's population. The majority of the population of Sub-Sahara Africa (SSA) resides in the rural areas. To these people, food security and sufficiency are the most impactful factors in their wellbeing. The form of energy used by this rural population for cooking and post-harvest preservation is predominantly firewood and charcoal. Their continuous use of firewood leads to the creation of greenhouse gases (GHGs), deforestation, health related issues as a result of smoke inhalation and the loss of quality free time by especially women and children who have to trek long distances to fetch firewood. The sustainable development of Sub-Saharan Africa is

greatly undermined by the needs of the rural inhabitants. A large proportion of harvested crops perish because of the absence of basic post-harvest technologies for their preservation. Amongst the renewable energy alternatives, the application of solar-thermal energy to domestic cooking and post-harvest crop preservation appears to be the most promising alternative to firewood use. Therefore in this work, we propose a concrete realization of an aspect of Sustainable Development Goal Number 7 (SDG7), to provide affordable and clean energy, by the application of solar-thermal energy to cooking and post-harvest crop preservation.

Thus, a pre-condition for food security in Africa is the development and deployment of effective and affordable cooking and post-harvest technologies for rural communities. The deployment of such technologies, on a continental scale, will break the perennial cycle of relative abundance and waste in one season and acute scarcity and hunger in another season as well as provide a clean alternative to the traditional use of firewood for cooking and post-harvest preservation (Toonen, 2009). Such innovation will also directly or indirectly impact the attainment of three other Sustainable Development Goals: SDG3, to ensure healthy lives; SDG8, to promote sustained, inclusive and economic growth; SDG15, to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt biodiversity loss. The potential to impact SDG15 results from a reduction of the pressure on forest exploitation for firewood used in cooking and drying of a variety of crops.

In this paper, an affordable and effective solar cooker/dryer for post-harvest preservation is proposed. A review of different solar cooker designs finds the solar box type(Muthusivagami et al., 2010, Geddam et al., 2015, Harmim et al., 2012) to be the most promising design in terms of cost, usability, safety and the ready availability of local materials for construction. However, long cooking times and solar intermittency have traditionally hindered the uptake of solar cooking technologies. We approach this by maximizing the absorption area exposed to the sun via the incorporation of a simple solar concentrator while ensuring an optimum, user-friendly design. This design will be adapted to generate heat required for drying: a common post-harvest preservation method. The combined effect of the solar concentrator and energy storage materials in the design has the potential of improving cooking and crop drying times as well as extending heat availability after dusk (Verma et al., 2022).

Design and Methodology

Truncated Double V-trough Solar Concentrator

The truncated double V-trough solar concentrator (see 5a) has been reported as the optimum design in terms of cost when compared to the truncated pyramidal design (Al-Najideen et al., 2019). In addition, both the truncated pyramid and V-trough solar concentrator designs are expected to be less dependent on solar tracking(Kumar et al., 2008). The inclusion of solar concentrators is aimed at boosting the energy collection without increasing the absorption window which could increase energy loss from the cooker. This is expected to achieve higher temperatures, an important requirement for cooking and drying.



Figure 39: (a) Double V-trough solar concentrator (b) the truncated pyramid box solar cooker (Verma et al., 2022)

Truncated Pyramid-type Solar Cooker

The truncated pyramid design for the solar cooker is used. This ensures that an optimum heating volume is used for the cooking process. The cooker used was constructed using 9 mm thick plywood with dimensions as shown in 6. The inner walls of the cooker were lined with 1 cm thick Styrofoam as a thermal insulator and inner surface finally dressed with highly reflective aluminium foil while the absorber plate at the bottom was made of a 1 mm cast iron (specific heat capacity of 550 Jkg⁻¹k⁻¹), painted black. The absorber window was double glazed 5 mm glass. This ensures that a higher temperature is achieved at the bottom and that heat loss is minimal.



Figure 40: Truncated pyramid-type solar cooker.

Energy Storage Materials

The use of solar energy for cooking/drying food is a well-known and attractive, clean method. Open solar drying for instance has a number of drawbacks most of which can be overcome by the solar box dryer. Introduction of thermal energy storage materials into these dryers/cookers has the potential of extending the cooking/drying period beyond dusk as well as improving the performance of these systems. Some of the common, natural and inexpensive thermal energy storage materials readily available to the rural communities include basaltic rocks and sand. The performance analysis of solar dryers/cookers with and without basaltic rocks as energy storage materials is investigated experimentally.

Experimental

The double-sided solar concentrator was used in this study. Four booster mirror reflectors used were each of dimensions 40 cm by 60 cm, thus the total area was 0.96 m². The reflectors were setup in a double V-trough configuration as shown in 5, with a grazing angle of 25°. This design has been found to produce optimum concentration of solar irradiance at minimal cost of reflectors (Al-Najideen et al., 2019). The absorption area of the solar-box cooker was designed to match the output area of the double V-trough solar concentrator (40 by 40 cm). The cooker was designed to take the shape of a truncated pyramid as shown in 6. This design has been found to produce a minimized cooker volume that would reduce energy wastage within. Combining the advantages of a double V-trough solar concentrator with those of the truncated pyramid-type cooker produces a single design with enhanced performance. Owing to the geometry of the solar cooker design, rays from the concentrator hitting the inner sidewalls (made of highly reflective aluminium foil) of the truncated pyramid cooker are reflected downward, so as to create a zone of high temperature at the bottom, resulting in improved convection during the cooking process (Kumar, 2004).

System Characterization

Stagnation Test (First Figure of Merit F1)

A number of no load tests were carried out on the solar box cooker to determine its stagnation parameters and the increase in temperature inside the cooker. The test was carried out for the different temperatures: stagnation temperature, ambient temperature ($T_{amb.}$) and absorber plate temperature (T_{plate}) were measured daily between 11:00 and 15:00 during the operation of the cooker in time intervals of 30 minutes. One of the figures of merit often used to characterize solar box cookers is the first figure of merit (F1) for the stagnation (see equation (1)) (Mullick et al., 1987). F1 is a parameter that is unique for every cooker and provides a means to measure the cooker performance.

$$F_{1} = \frac{\eta_{o}}{U_{L}} = \frac{T_{P} - T_{a}}{I_{s}}$$
 (1)

Concentration Ratio

The solar cooker depends principally on sunlight for its operation. Hence the need to collect the sun's rays over a large area and concentrate them to a small but optimum surface of the cooker grazing area. The maximum collection occurs when the collection surface is perpendicular to the sun's rays. For countries near/at the equator, this condition is achieved at midday with maximum solar intensity. Solar concentrators are characterised by the geometric concentration ratio (CR). The CR is often defined as in equation 2.

$$CR = \frac{A_t}{A_{as}} \tag{2}$$

where A_t is the total perpendicular collector area and A_{as} is the area of the absorber surface.

Estimation of Optimum Solar Reflector Dimensions

The base of the double V-trough truncated solar concentrators was designed to be 40 cm by 40 cm to match the absorption surface of the solar-box cooker used. However, in order to minimize the cost of the reflectors, the length (L) of each of the four reflectors used was optimized for normal incidence that gives rise to minimal ray rejection. Using the design diagram shown in 7 (the angles *i* and *r* represent the incident and reflected angles respectively), the relationship between the grazing angle (α), the absorber width (b) and L is given by equation 3.

$$b = L(\cos(\alpha)\tan(2\alpha) - \sin(\alpha)) \quad \dots \quad (3)$$



Figure 41: Design structure of the optimal truncated V-trough solar concentrator

Results

The results of stagnation temperature test (8) for the designed solar box cooker without energy storage material shows a maximum no load achievable temperature of about 93 ^oC. This cooker maintains a high temperature (above 80 ^oC) for duration of 2 hours between 11:30 and 13:30. Using equation (1), F1 is calculated to be about 0.07 Km²W⁻¹.



Figure 42: Stagnation temperature test of solar cooker without energy storage material for first figure of merit (F1), measured on the 13th of March 2022.

Figure 43 shows the plot of concentration ratio of the solar concentrators. A maximum ratio of 2.1 is obtained in a typical experiment. This is less than the geometric concentration ratio of 3.5 for this system as calculated using equation (2). From Table 2, it can be seen that the optical efficiency of the concentrators estimated by dividing the intensity ratios by the geometric concentration ratio varies between 30 and 60 %. The optical efficiency peaks at 12:00 as the system design was optimized for maximum concentration at normal incidence (see equation (3). This condition would be satisfied at around 12:00 for Buea, location of experiment (Latitude 4° 9' 33.4872" N and Longitude 9° 14' 36.7296" E).

			ls	ls-	Optical efficiency
Time	T _{amb} (0C)	T _{plate} (0C)	(W/m2)	C/Is	(%)
11:00	27.1	72.4	767	1.17	33.26
11:30	31.1	85	740	1.69	47.75
12:00	32.4	90.1	628	2.11	59.59
12:30	32.8	90.4	667	1.72	48.53
13:00	34.2	93.2	722	1.91	54.03
13:30	33.4	80.6	675	1.46	41.32
14:00	31.3	63.6	554	1.07	30.26



Figure 43: The plot of the ratio of the solar insolation obtained from the concentrators (Is_c) to the insolation (Is)

Figures 10 and 11 show the graphs for the stagnation temperature tests with solar-box cooker containing 1 kg of basaltic rocks pellets with average diameters of 13 mm and 5.6 mm respectively. An estimation of the figure of merit F1 gives the same value of 0.06 in both cases. This suggests that cooker performance was likely to be independent of the pellets size. The incorporation of the storage material into the solar cooker however resulted in a reduction in F1 by about 14%. Similar observation has been made by (Verma et al., 2022). In all cases, effective cooking could be possible between 11:30 and 13:30 when the temperature within the cooker remains fairly high.



Figure 44: Stagnation temperature test of solar cooker with 13 mm diameter basaltic pellets of energy storage material for first figure of merit (F1), measured on the 15th of March 2022.



Figure 45: Stagnation temperature test of solar cooker with 5.6 mm diameter basaltic pellets of energy storage material for first figure of merit (F1), measured on the 16th of March 2022.

The perspectives for further work include:

- Production of one hundred prototypes for partner NGOs to use in sensitizing rural communities in the South-West Region of Cameroon
- Partnership with a Cameroon-based company for mass production

Conclusions

The solar-box cooker design proposed in this work has the potential to reduce cooking time due to the incorporation of the concentrator. The prototype is designed for low cost so that it can be affordable in SSA. It attains its maximum output when the solar intensity is maximum, a common characteristics shared by most Sub-Saharan African countries. This ensures that maximum thermal energy is extracted during periods of maximum intensity. The double V-trough solar concentrator design used has been found to show minimal dependence on tracking. A drawback with this design is that the solar concentrators are optimized for maximum concentration at noon and contribute minimally at other times. The experimental results obtained from the thermal performance tests F1 show that the performance of the solar-box cooker is not affected by the size of pellets of storage materials. In addition, the work provides an experimental support to the observations made by (Verma et al., 2022) via simulations.

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Financing Sustainable Energy in the Ghanaian Energy Market – A Comprehensive Policy Review and Recommendations

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Abstract

The paper keeps sustainable development goal (SDG) 7 – affordable and clean energy – as its focal point, primarily focusing on enabling "affordability" of sustainable and clean energy sources. The goals of this paper are threefold. The first is to provide an overview of Ghana's energy policy and apparatus. The second is to evaluate and highlight design flaws in the policy support mechanisms and financing constraints that dampen investor confidence and affect the risk profile of RE projects. Moreover, finally, to recommend alternative policies and fiscal mechanisms such as tax-based incentive structures that stimulate a broader base of equity financing participation; financially engineered securitization model of renewable energy assets to offset the inadequacies of the traditional means of project financing in order to create an enabling environment to accelerate the transition to affordable and clean energy.

Keywords: Ghana, SDG 7, renewable Energy, cost of financing, liquidity shortfalls, securitization.

Abbreviations

AAGR	Average Annual Growth Rate
ABS	Asset-backed Securities
BoG	Bank of Ghana
CAGR	Compounded Annual Growth Rate
CAR	Capital Adequacy Ratio
CSP	Cross-Sector Partnership
EC E	Energy Commission
ECG	Electricity Company of Ghana
EPPs	. Emergency Power Producers
ERP	Economic Recovery Program

- ESLA..... Energy Sector Levy Act
- ESRP..... Energy Sector Recovery Program
- FDI..... Foreign Direct Investment
- FiT..... Feed-in-Tariff rate
- GDP..... Gross Domestic Product
- GEDAP..... Ghana Energy Development and Access Project
- GH¢..... Ghanaian cedi
- GoG..... Government of Ghana
- IMF..... International Monetary Fund
- INR..... Indian Rupee
- IPPs..... Independent Power Producers
- IRR..... Internal Rate of Return
- KW..... Kilowatt
- kWh..... Kilowatt per hour
- LIBOR..... London Interbank Offer Rate
- LLC..... Limited Liability Company
- MBS..... Mortgage-backed Securities
- MFI..... Microfinance Institutions
- MFL..... Microfinance Loans
- MoE..... Ministry of Energy
- MoF..... Ministry of Finance
- MW..... Megawatt

- MWh..... Megawatt per hour
- OBSV..... Off-balance-sheet Vehicle
- OPEC..... Organization of the Petroleum Exporting Countries
- PAYGo..... Pay-as-you-go
- PPA..... Power Purchase Agreement
- PSL..... Priority Sector Lending
- PURC..... Public Utilities Regulatory Commission
- PV..... Photovoltaic
- PWD..... Public and Words Department
- RBI..... Reserve Bank of India
- RE..... Renewable Energy
- REA..... Renewable Energy Authority
- REC..... Renewable Energy Certificate
- REMP..... Renewable Energy Master Plan
- RPO..... Renewable Energy Purchase Obligation
- RPS..... Renewable Portfolio Standard
- SBUs..... Strategic Business Units
- Scfd..... Standard cubic feet per day
- SDG..... Sustainable Development Goals
- SHS..... Solar Home Systems
- SNEP..... Strategic National Energy Plan
- SOEs..... State-owned enterprises

SPV	Special Purpose Vehicle
USD	. United States Dollar
VALCo	Volta Aluminum Company
VGF	Viability Gap Funding
VRA	Volta River Authority
WACC	Weighted Average Cost of Capital
WAGP	West African Gas Pipeline

Introduction

The agenda of energy sustainability has been at the forefront of global development, reiterated on numerous national and global platforms. The most prominent one is the adoption of the Sustainability Development Goal 7 (SDG 7) under the United Nations 2030 agenda for sustainable development. The agenda aims to facilitate universal access to reliable, affordable, and clean energy, further driving nations towards a sustainable energy future. According to the World Bank 2017 SDG targets review, SDG 7 has synergistic effects on 125 out of 169 SDG targets. (World Bank, 2017). Therefore, a state that understands the synergistic effects of access to modern energy services on economic growth, alleviating poverty, and national development, highly prioritizes mobilization of renewable energy (RE) into its energy mix.

The paper focuses on the renewable energy sector of the Republic of Ghana – a country that is often seen as a model for other emerging African countries. (UNDP, n.d.) With abundant and favourable natural conditions, Ghana is well-suited to adopt a sustainable energy model. However, historical trends show that Ghana faces significant sectoral issues concerning inefficient capital allocation, policy inconsistency, insufficient fiscal incentives, financing limitations, and an overall lack of institutional support to develop a sophisticated renewable energy model. With the energy sector financing potential bottled up by unprofitable tariff structures, operational inefficiency, and contingent liabilities adding to its public debt stock, there is a massive disconnect between the need for SDG 7 financing and the availability of capital resources. This has called for a need for unleashing vast amounts of private capital to bridge the financing gap needed to accelerate the deployment of RE assets.

The following study is divided into three sections – section I presents a historical correlation between economic growth and energy demand in order to highlight the inadequacy of the current energy model, and recommends adoption of a macro-scaled RE model to meet future energy demand. Secondly, section II dissects the strengths and weaknesses of the current renewable energy model. Finally, Section III recommends alternative regulatory frameworks and financing

structures that hold the potential to resolve sector weaknesses and enable Ghana to meet its SDG 7 goals.

Methodology

The paper primarily utilizes a mixed-method research approach from secondary sources to identify and review the key drivers of the Ghanaian renewable energy market. This research implements an inductive approach to identify the bottleneck factors that prevent Ghana from achieving its SDG 7 targets.

In addition, a qualitative approach is implemented to recommend alternative methods to incentivize the Ghanaian renewable energy apparatus. Data for this study is gathered from the World Bank database and country reports, Government of Ghana reports, Bank of Ghana database, annual reports of Volta River Authority, and from the existing literature and documents on the sector.

Results

Section I

Background: Historical Economic Trends and its Effects on the Ghanian Energy Sector

Embryonic Phase (1900s – 1970s)

Under the Volta River Development Act, 1961, the government of Ghana (GoG) established the Volta River Authority (VRA). Its primary function – to construct and operationalize the Akosombo Dam over the Volta River and take charge of the duties of energy production; supply produced electricity to the Volta Aluminum Company (VALCO); and transmit the remaining energy to the transmission system. The construction of the Akosombo Dam in 1972 gave rise to the first phase of the Ghanian energy sector – hydropower.

During this period, Ghana followed a macroeconomic policy of lax fiscal management coupled with expansionary credit policy. In December 1972, the Bank of Ghana set the monetary interest rate to a historic low of 6.0% (Bank of Ghana, 2021c). Between 1972 and 1982, the money supply grew at an average of 39.1%. (World Bank, 2020a) As low-interest rates worked their way into the economy, industrial expansion and consumer spending fueled by cheap credit led to inflationary economic growth. Inflation between 1972-83 averaged at 57.3%, peaking at 122.9% in 1983 (World Bank, 2020c). With a rapidly rising urban population and the industrial and service sector expansion due to monetary expansions of the late 70s, energy demand surged nearly sixfold. By 1976, the total domestic energy consumption peaked at about 3917GWh from 540GWh in 1967, growing at an average annual growth rate (AAGR) of 10%. (Volta River Authority, 1980)

Second Coming (1980s - 2000s)



Fig 1. Trends in Energy supply and demand from 1970 to 1990 Source: (VRA, 1980); (VRA, 1991).

In late 70s – early 80s, the Ghanian economy went into a downward spiral, due to a series of exogenous shocks, particularly, the second OPEC crude price hike of 1978-79 – where the spot price shot up from \$12.70 in 1978 to \$40 per barrel by June 1979 (The New York Times, 1979). As a result, weak industrial production, and government failure to adjust domestic petroleum prices to the rising global prices of crude, led to an increase in the budget deficit by 44.94% (Dadson et al., 2018); (Ocran, 2007).

Failing to recover from the oil crisis, Ghana was hit by another energy and labour supply shock in 1983 – when Nigeria decided to clamp down on the oil supply (Brydon, 1985), and expel one million Ghanaians, which increased the domestic labour supply by 10% (World Bank, 1985; Van Hear, 1992). The economic crisis was further exacerbated by a severe drought that led to the devastation of agricultural production; widespread bushfires destroyed cocoa production – a cash crop whose export revenues the Ghanaian economy heavily relied on (Kolavalli and Vigneri, 2011). The drought of 1983 caused severe distortion in the generation capacity of the Akosombo dam – a primary energy production apparatus. Between the periods of 1982 and 1984, the total inflow was less than 15% of the projected total (ISSER, 2005). As represented in Figure 1, the total electricity production went down from 5180GWh in 1981 to 1670GWh in 1984 (VRA, 1985). The following episode revealed a major electricity supply security issue within the Ghanaian energy apparatus.

Crumbling economic infrastructure and energy systems led the government to adopt the Economic Recovery Program (ERP), a market liberalization approach supported by the Fund and

the World Bank (Nowak et al., 1996). The fundamental principles driving economic reform were – a progressive shift away from state intervention; enhancement of institutional reforms to boost private investment and activity; and restoration of fiscal prudence (Nowak et al., 1996). The program's initial phase brought about economic stabilization – the real GDP growth rate (%) went up from -6.9% in 1982 to 8.6% in 1986, further stabilizing at the target rate of 5% a year (World Bank, 2020b). Consequently, economic recovery was on the way, and so was the rise in power demanded. As a result, the energy consumption shot up from 1670 GWh in 1984 to 5110 GWh in 1991 (VRA, 1991).

In 1993, Ghana experienced another drought, leading to power rationing and loss in industrial output. The '93 power crisis sent a message to the VRA and the Government of Ghana (GoG) that the policy of over-reliance on hydropower was flawed, and there was an urgent need to diversify the energy production mix of the country (Martin et al., 2001). A capital injection of USD 1.5 billion would be needed to finance the development of electricity apparatus to keep up with the rising power demand (Martin et al., 2001). Calls for reforms in Ghana came when World Bank installed a policy of "commitment lending" - where there was a systematic relationship between the volume of aid granted and the extent to which African countries were committed to economic reforms (Devarajan et al., 2001). Urgent need to develop power production capacity and attract World Bank and private capital into the sector led to the power reforms of 1994. The government of Ghana (GoG) opted for a "competitive model" for its power sector, which entails inter alia private participation in energy production and unbundling of the vertically integrated monopoly of VRA into Strategic Business Units (SBUs) (Martin et al., 2001). By 1997, GoG implemented significant sectoral structural reforms such as the establishment of independent regulatory bodies - Public Utilities Regulatory Commission (PURC) (Act 538), overseeing and setting of end-user energy tariff prices; and the Energy Commission (EC) (Act 541) overseeing licensing and regulatory environment of the sector (Energy Commission, n.d.). Satisfied with the GoG's commitment to reform the energy sector, the World Bank approved a USD 176 million credit facility for the 330 MW Takoradi Thermal Plant, leading to the second phase of the energy sector - diversification of energy mix into thermal energy (Martin et al., 2001).

By the mid-2000s, Ghana had undergone several climatic shocks – 1983-84, 1997-98, 2003, 2006-07, which directly affected energy production and, consequently, industrial production and economic growth. Economic growth was cut down by about 2%, from 6.4% in 2006 to 4.3% in 2007 (World Bank, 2020b). According to Databank Ghana, the power outage and rationing of 2007 forced companies to spend about USD 744 million a year to offset power deficiencies, which was about 6% of Ghana's economic output (Phillips, 2007).

Sector Maturity (2010s-present)



Fig 2. Trends in Energy supply and demand from 2000 to 2020 Source: (Energy Commission, 2020b)

Since the 2010s, the country's energy sector is in its third phase of hydro-thermal energy production model – about 51.8% and 48.2% of the total generation capacity (2010 data), respectively (EC, 2020b).

Ghana has experienced a repeating climatic trend of rainfall shortage during the dry season of 2012, lowering the water levels at Akosombo. Alternatively, the majority of the thermal power generating systems rely on Nigerian gas via the West African Gas Pipeline (WAGP). In 2013, due to infrastructural damages, Nigeria diverted gas to its domestic market, leading to a severe gas supply shortage – 30m-50m standard cubic feet per day (scfd) compared to 123m scfd as per the WAGP agreement (Oxford Business Group, 2017). The combined effect of low water levels at hydro-dams and difficulty in fuel acquisition for thermal plants resulted in severe power shortages and extended periods of blackouts, leading to the local adoption of the word "*Dumsor*," which literally translates to "*on and off.*" The energy crisis had a significant impact on the total factors of productivity – the manufacturing shrunk by about 8% during Q4 of 2014 (Mensah and Smith, 2018). In response to the crisis, the Electricity Company of Ghana (ECG) hastily signed 42 "take-or-pay" based Power Purchase Agreement (PPA) with the IPPs. In addition, the MoE signed three additional PPAs with emergency power producers (EPPs) (Ackah et al., 2021). The fiscal ramifications of this erratic response to the power crisis trickled down in subsequent years.

The following years were dominated by government policy of sectoral debt management and fiscal adjustment programs to improve the financial sustainability of the energy sector. Due to inefficient operational management and uneconomic end-user tariff structure, the energy sector

SOEs experienced heavy financial losses – 32.1% of the total revenue in 2014 to 40.7% in 2015 (Institute for Fiscal Studies, 2018). As for VRA, two primary sources of financial losses were due to guasi-fiscal subsidies provided to VALCo and heavy discount in wholesale tariff that accounted for only 78% of the cost recovery levels (International Monetary Fund. African Dept., 2021). The build-up of excess energy capacity payment offloaded by the IPPs under the "take-or-pay" based PPAs signed during the 2012-2015 power crisis began to take a heavy toll on the bottom line of SOEs financials. In 2017, the Ministry of Finance (MoF) incorporated a special purchase vehicle (SPV) – Energy Sector Levy Act (ESLA) Plc. – to refinance rising sectoral debt. The SPV issues debt securities backed primarily by receivables from ESLA Act - levies imposed on goods and services. By Q1 of 2019, the net sector arrears within the energy and gas sectors were outstanding at about USD 2.75 billion – 33% of 2018 tax revenue (Ministry of Energy, 2019). Costs involving energy sector arrears rose the budget deficit from 7.5% of the GDP in 2019 to 15.2% in 2020, whereas public sector debt grew from 63% of GDP in 2019 to 79% in 2020 (IMF, 2021). In 2020, the government paid more than USD 1 billion for unused electricity (The Energy Year, 2022). Hence, the Ministry of Energy (MoE), in collaboration with MoF, initiated a comprehensive debt restructuring and sector stabilization and recovery program - Energy Sector Recovery Program (ESRP) (MoE, 2019). The key recommendations of the program involve aggressive renegotiations of PPAs with IPPs; review of plausible increase in power sector tariffs; oversee sector stabilization payments to ensure the financial viability of SOEs; and shift from practice of "take-or-pay" basis to a competitive procurement of future PPAs (MoE, 2019).



Fig 3. Trend between GDP growth rate (%) and Change in Energy Consumption (%) (1970-2021) Source: (World Bank, 2020b); (Energy Commission, 2020b)

Proactive management and effective implementation of the recovery program yielded in commendable results – just by the end of 2020, the government had saved USD 5 billion in PPA renegotiation (Glover, 2021); (GhanaWeb, 2022). With fiscal deficits narrowing from 15.2% in 2021 to 9.1% in 2022; forecasted average inflation slowing at 9.0% in 2022 from 9.8% in 2021; and projected GDP growth rate climbing up to 5.5% in 2022 from 0.4% in 2020, economic recovery is underway. (FitchRatings, 2022a).

Historical trends, as seen in Figure 3, show a strong correlation between economic recovery and increasing energy demand. In the past five years, peak power consumption has risen at an AAGR of around 10.3% - largely due to rapid urbanization expansion of the industrial and service sector (especially banking and hospitality subsectors). Therefore, while supply apparatus meets current power demand, total demand is estimated to outpace supply capacities by 2025, further outpacing by 392 MW (The Energy Year, 2022). The current MoE policy of ESRP shows a huge potential for the sector to recover from its financial distress, creating opportunities to implement innovative incentive structures and use the available financial dry powder into diversifying its energy production portfolio. Rising power demand, sectoral improvement, and governmental commitment to promote energy security and efficiency opens up a new opportunity for Ghanaian energy sector to transition into the final phase – renewables.

Section II – Efficiency of Renewable Energy Act and Financing Shortfalls.

To transition towards the next phase of energy production and achieve the SDG 7 targets, there is a need to develop a long-term integrated roadmap and a guiding framework that incentivizes rapid development of RE apparatus. In Ghana, the policy inertia started to build up in the renewable energy sector after the power crisis of 2012-2016. To create an incentivizing fiscal and regulatory regime, the Ghanaian parliament enacted the Renewable Energy Act 2011, Act 832. Support instruments and incentive mechanisms developed under the act include:

Feed-in-Tariff (FiT) Scheme (Amended to Competitive Procurement Scheme)

FiT scheme is considered as one of the most effective price incentive policies adopted around the world for stimulating the rapid development of RE activity. The central principle behind the scheme is to create a stable and predictable cash flow by setting a fixed price or by providing a premium over the current market tariff for every kWh of power generated by renewable sources. FiTs guarantee fixed premiums over the lifetime of RE projects that generally have high upfront costs and overall high fixed to variable cost ratio. Therefore, FiTs can dramatically offset the price variability risk of a project and create an enabling environment for sectoral growth.

Under the RE Act 2011, Ghana opted for the "fixed price model," where the FiT rates chargeable are guaranteed for a period of 10 years and thereafter subject to review every two years. (Renewable Energy Act, 2011).

However, one of the key issues with the FiT scheme is difficulty optimizing tariff rates that offer "fair" compensation. Unfavorable tariff rates create competitive distortions in the energy markets
as financially distressed state utilities are obligated to procure electricity at too high a price when compared to underlying competitive market prices. The Ghanaian tariff structure offered about 0.15-0.18 USD per kWh, significantly higher as compared to the other developing countries (Nii, 2016); (PURC, 2016).

In order to drive down the financial burden on utilities and consumers, Ghana replaced the FiT scheme with the Competitive Procurement Scheme, also known as demand auctions. (RE (Amendment) Act, 2020); (Parliament of Ghana, 2020). The procurement takes place according to annual energy supply and demand projections. A fixed capacity (kW) or power generation quantity (kWh) is auctioned for competitive bidding, and a producer that offers to generate at the lowest cost obtains the government tender. The shift towards demand auction model resulted in a reduction of tariff rate from 0.18 USD per kWh to less than 0.10 USD per kWh (Afful, 2020).

Renewable Energy Purchase Obligation (RPO)

RPO acts as an ancillary mechanism to the FiT scheme, which mandates the distribution utilities to procure a specified percentage of its electricity from renewable sources (RE Act, 2011). The PURC, in consultation with the EC, determines the specific percentage of required obligation. RPO framework is supplemented with Renewable Energy Certificates (RECs) – tradable certificates that account for verifying compliance with the purchase obligation. Purchase of a REC verifies procurement of 1MWh of energy by a bulk customer; the following certificate can be traded and exchanged in order to meet the regulatory compliance. Joint implementation of FiT scheme, RPO, and an exchange market for RECs are globally used to create an effective RE market.

However, the entire system collapses if the regulatory bodies are ineffective in enforcing RPO compliance unto power utilities. The RE Act specifies penalties charged for non-compliance but remains ambiguous regarding how the obligations are supposed to be met – whether utilities can trade RECs or do they need to self-generate to meet their purchase obligation. In addition, the public utilities are under severe financial distress, resulting in failure to meet its purchase obligations. Even though the legislation has deployed a definite Renewable Portfolio Standard (RPS), regulatory failure to enforce purchase obligations and financial incapacity to effectively procure electricity from RE sources has rendered the entire incentive system ineffective.

Renewable Energy Fund (RE Fund)

The RE Act has provided for the establishment of the RE Fund. Its primary objective is to enable capital for 'the promotion, development, sustainable management, and utilization of renewable energy sources' (RE Act, 2011). The Act specifies that the funds are to be channelled into renewable energy activities such as – payment of FiT rates, financing of grid integration and infrastructure, providing resources for off-grid and mini-grid RE power systems, and equity participation.

Capital for the Fund comes from – budget allocations approved by the Parliament; premium paid to the EC for failure to meet RPO compliance; donations and grants received for RE activities;

funds approved by the Board of Energy Fund under the EC Act, 1997 (Act 541); funds approved by the MoF; and levies collected from the export of biofuels as approved by the Parliament (RE Act, 2011).

That said, under the Renewable Energy Master Plan, 2019 (REMP), the government acknowledged the lack of concessional funding sources for RE activities; in turn, the MoE signaled a strong intention to operationalize the Fund during the first cycle (Cycle I) of the REMP (EC, 2019). However, as of today, the RE Fund is yet to be operationalized (MoE, 2020).

Renewable Energy Authority (REA)

To enter the energy market, renewable energy IPPs need to go through complex bureaucratic procedures to obtain various licenses and approvals to initiate final operation. A typical licencing process goes as follows - the IPPs initiate the procedure by undertaking pre-feasibility studies and conducts detailed studies on the technical and financial viability of the project; after the project is deemed viable, IPPs go through three stages of acquiring various licenses – Stage 1 involves the acquisition of a provisional license; Prior to construction, Stage 2 involves obtaining siting clearance permit, and a permit to authorize construction of the project; Stage 3 deals with the permit to authorize the operation (EC, 2012). Throughout this cumbersome licensing process, IPPs deal with various regulatory agencies such as, PURC, EC, the Environmental Protection Agency (EPA), MoE, MoF, and the Ghana Investment Promotion Agency. The complexity of the licensing regime leads to high transactional and administrative costs, adding to the already high upfront costs.

Furthermore, the onsite deployment of RE projects has been minimal due to the absence of a "one-stop-shop" system to streamline and fast-track the project approval process (Climate Investment Funds, 2015). As of 2020, 130 proposals were submitted for Wholesale Electricity Supply Licenses with a total capacity to produce 7030.6 MW of electricity from RE sources. 40 Licenses were approved for the siting clearance permit; further, 13 licenses were issued with Construction Permit; however, only four licenses were granted with the Operational permit, which is about 3% of the potential IPPs waiting for approval (EC, 2020a).

Therefore, to streamline the bureaucratic and regulatory process, GoG made provisions for the establishment of an independent regulatory body. Section 53 of the RE Act called for the establishment of Renewable Energy Authority (REA). Its functions – to oversee implementation of RE activities, execute state-sponsored RE projects, and manage the state assets related to renewable energy (RE Act, 2011).

However, 11 years after the adoption of the RE Act in 2011, REA is yet to be established (MoE, 2020). Under the plans laid out for cycle I (end of 2020) of the REMP, the government affirmed to operationalize the REA. Nonetheless, as of 2022, these efforts remain futile. Failure to institute an independent sectoral regulatory body points at legal and political noncommitment, in effect, hampering investor confidence.

Liquidity and Interest Rate Shortfalls Towards RE Project Financing

One of the major disabilities with RE projects are its high upfront and installation costs; due to this fundamental characteristic of capital requirement, access to long-term, low-cost debt financing is vital for the development of RE projects. However, The Ghanaian project financing market is riddled with high lending rates and liquidity shortfalls. For commercial banks, when liquidity risks, prime rate, and minimum reserve requirement regulations are taken into consideration, funding capital intensive renewable energy projects becomes less appealing.

For instance, credit institutions need to comply with liquidity requirements such as Capital Adequacy Ratio (CAR), a metric of a bank's capital in relation to its risk-weighted assets and current liabilities (BoG, 2021a). This metric aims to promote short-term credit resilience to potential financial risks. The following ratio is reproduced as:

$$CAR = \frac{Tier \ 1 \ Capital + Tier \ 2 \ Capital}{Risk \ Weighted \ Assets} \ge 21\%$$

As of March 2021, the Bank of Ghana set the minimum CAR at 21% (BoG, 2021b). Financing capital intensive energy projects worsen the institution's capital adequacy ratio due to their perceived risk, raising the cost of capital for the intended project.

Further, looking at the demand side of the debt market, users of capital are primarily companies, individuals, and the government. Fiscal deficits and a government with a huge appetite for borrowing, influence the prices and lending rate of the available capital. To enable borrowing, the government issues securities with high coupon rates, attracting capital towards government bonds, further crowding out private borrowers (Kwakye, 2010). For example, EcoBank Ghana PLC, Ghana's second-largest bank, has a significantly high sovereign exposure (about 43% of its total assets) to public sector lending (FitchRatings, 2022b).

	Solar PV Projects				Government Securities (T-bills)		
Description	BXC	GCP	Nzema	Navrongi	91-day	182-day	364-day
Rate Of Return (RoR)	21.3%	10.5%	7.5%	16.4%	14.7%	15.2%	18.2%

Table 1 – RE project RoR v/s Ghanaian T-bill coupon rate Sources: (Pueyo, 2018); (Aguilar, 2015) ; (Bank of Ghana (BoG), 2021c).

International financing, including concessional financing, offers an average lending rate of 7.5%; in comparison, the domestic lending rates are between 21% to a whopping 37%. (Pueyo, 2018). Though, the commercial lending rate averaged at about 21% by 2021 (BoG, 2021c). Targeted Internal Rate of Return (IRR) demanded by equity investors can be as high as 30% to consider the RE project economically viable (Pfan et al., 2015). Comparing the risk-return profiles of RE

projects in Ghana with other investment alternatives such as government securities, as illustrated in (Table 1), energy projects fail to act as lucrative investments. Two elements keep the returns low - on one side, high cost of capital, whereas on the other, governmental intervention in keeping electricity prices below market level, further eroding the price competitiveness of renewable energy.



Fig 4. Eurobond Spreads between Ghana and JP Morgan Emerging Market Bond Index (EMBI+) (basis points) Source: (IMF, 2021)

The only project that seems economical, as seen in Table 1, is the 20MW solar PV plant developed by the Beijing Xiaocheng Technology (BXC) China – USD 30 million project financed by the Chinese development banks that offer soft loans and credit at an interest rate of 4% to 5% (LIBOR + country risk premium) (Pueyo, 2018). Significantly lower when compared to the rates offered by the international concessional loans and domestic credit institutions. On top of low borrowing costs, the project was able to access low construction costs due to Chinese construction contractors; the factoring effects of low financing and factor costs led to the production of cost-competitive electricity (Pueyo, 2018).

Finally, macroeconomic stresses on liquidity have put pressure on domestic borrowing costs (FitchRatings, 2022c). Ghana, during the COVID-19 pandemic, has experienced tightening of external credit conditions – Foreign Direct Investment (FDI) has fallen from 4.4% of GDP in 2019 to 2.7% of GDP in 2020; whereas Net foreign portfolio flows bottomed down to 2.3% of GDP in 2020 from 3.4% of GDP in 2019 (IMF, 2021). Public sector debt has risen from 63% of GDP in 2019 to 79% in 2020, having sharply increased debt service costs and the governmental need for credit (IMF, 2021). To meet its debt obligations, Ghana has heavily relied on international capital markets; for example, the Euro-denominated bond series issued by the GoG dating back to 2018, raising a cumulative of about USD 8 billion in 2020 (Graphic Online, 2021). However, increasing bond spreads between the Ghanaian Eurobond and Euro-denominated bonds from other emerging markets, as illustrated in Figure 4, show faltering investor confidence towards the Ghanaian security. For example, The Eurobond series issued in 2021 totalled USD 3.03billion at 8% with an average maturity of 11years; comparing that to the issuance of USD 3billion Eurobond,

in 2020, which offered 7.5% with an average maturity of 17years, it can be concluded that the cost of external financing has significantly increased (IMF, 2021).

Consequently, the government has heavily relied on domestic credit markets to absorb its credit requirements. This overreliance has pushed domestic absorption capacity to the limit; with over 40 per cent of the domestic banking sector assets exposed to sovereign credit, the supply of money relative to demand has decreased, further raising the risk of interest rate pressures (IMF, 2021). In turn, the supply of appropriate financing for renewables has nearly vanished.

That being the case, there should be a systematic attempt to explore innovative alternative debt financing mechanisms, tax-based incentive structures, and regulatory measures to improve the current condition of capital flows towards the RE sector.

Section III - Recommendations

Bundling and Viability Gap Funding (VGF) Scheme

The following federal policy practices recommended in this subsection takes inspiration from the action plan of the Government of India's 2009 National Solar Mission (Government of India, 2008). The mission unfolds into two phases – with Phase 1 primarily dealing with the bidding for RE project development and Phase 2 dealing with reverse bidding for government capital grants.

Phase 1 implemented procurement methods such as competitive auctions and the bundling scheme. As discussed in the previous section, Ghana has the necessary experience with competitive procurement auctions, which has lowered the tariff rates by 44% (Afful, 2020). Ghana, as implemented in India, can adopt the bundling mechanism that has helped reduce the effective procurement costs for the Indian distribution companies by 70% (Thapar et al., 2016). Under this scheme, a regulated intermediary would carry out price auctions where IPPs can bid with a composite tariff rate for RE-based power combined with a single conventional means of power (gas or coal) (Government of India, 2008). The Indian scheme mandates an electricity supply of at least 51% from RE sources. Ghana can adopt a more gradual approach of periodically increasing the mandated supply mix, which can help ease out challenges associated with energy transition.

Furthermore, phase 2 of the mission introduced equity grants for solar projects. The Viability Gap Funding scheme was implemented to lower the equity financing burden on project developers. The exact amount of capital grant was determined by employing reverse auction, where developers bid down on the required funding per MW. VGF lowered the equity investments made by project developers from 30% to 15% (Thapar et al., 2016). Further, reducing the weighted average cost of capital (WACC) from 13.9% to 11.5% (Thapar et al., 2016). The scheme fuses market competition with the need for government financing. The implementation of reverse auctions for capital grants can help further reduce financing pressures on the government's coffers.

The paper recommends implementing the following schemes together, as their synergies can have a significant impact on reducing upfront equity as well as financing costs for RE developers.

Tax Equity Financing Structure

Governments conventionally subsidize sector activities through implied taxes. In project financing, tax subsidies are claimed directly by the developer engaged in the subsidized activity. However, under several other tax credits, the developer is often encouraged to partner with a third-party investor. These partnerships happen partially due to the intended party having minimal tax liabilities to offset, making the tax credits redundant, or because the tax credits are delivered over a long period, whereas, the developer needs short-term upfront financing to develop the project. The following conundrum can be solved by tax-equity partnership structures, where the primary tax beneficiary agrees to transfer rights to the tax credits to an investor in exchange for equity. The main objective behind developing tax-equity structures is to incentivize equity financing participation into the project's capital structure. A typical capital structure for financing RE projects – about 35% ($\pm 5\%$) of equity comes from the tax-equity investor, whereas the developer finances the rest via equity and debt (Martin, 2021).



Fig 5. All-equity partnership flip example structure

While multiple tax equity structures can be implemented – partnership flips, sale lease-backs, and inverted leases – varying per transactional needs, they often share standard structural features. Due to the scope of this paper, the section focuses on arrangements that use partnership flip structures. Figure 5 provides a visual summary of how the transaction works (debt not included

for simplicity). The transactional structure is relatively simple – a developer and a tax-equity investor, usually large financial institutions with a large tax liability, create a partnership or a joint LLC. The tax-equity investor injects equity into the LLC for 99% of the tax benefits upfront and with some agreed-upon percentage of cash benefits. Whereas the project developer retains most of the cash benefits associated with the project until full investment recovery. Thereafter, the cash benefits flow to the tax-equity investor. Once the tax-equity investor has reached a target yield (yield-based flip) or the transaction has reached a predetermined time (fixed-flip), the partnership will "flip" the allocation of the benefits. The developer will retain over 90% of the cash benefits post-flip, further having the right to buy out the remaining project interest of the tax equity investor. Thus, being the sole owner of the developed project (Bolinger, 2014).

Under the Ghana Investment Promotion Act (Act 865), investors are provided with significant tax reduction credits to the infrastructural development of RE projects (Ministry of Power, 2015, thus providing the building block of regulatory support for structuring tax-equity transactions in Ghana. However, there is a need for a comprehensive taxation framework – creating a type of tax credit that offsets the beneficiary's liabilities, cedi-to-cedi, in order to develop a sophisticated tax-equity investment market.

Microfinancing Loan (MFL) Securitization

This section recommends implementation of securitization structures to the world of microfinance lending. In order to better understand how the recommended securitization models would create an alternative financing market for the RE sector, a guided overview of the Ghanaian microfinance sector as well as introduction to securitization theory is needed.

Overview of Ghanaian Microfinancing Sector

Microfinancing infrastructure encompasses providing financial products that offer micro-credits and loans to low-income clients that are generally not catered by the formal banking institutions of the country. MFIs fill up this supply gap by employing sustainable financing practices. Microfinancing practices have significantly enhanced the financial inclusion of individuals and households at the bottom of the socio-economic pyramid, further improving social indicators such as poverty, education, and health (UNCDF, 2005).

Ghana, in the 2000s, saw a rapid growth in the spread of microfinancing activities which enabled broadening and deepening of the population base that was financially included in the banking sector. Clients catered by MFIs increased to around 8million by the end of 2013, rising from 1.3 million in 2001, while deposits and loans grew at a compounded annual growth rate (CAGR) of 21% and 26%, respectively (GHAMFIN, 2014). According to the (Global FINDEX, 2017, about 57.7% of Ghana's adults had a bank account in a formal financial institution in 2017 compared to 29% in 2011.

The period of boom oversaw major financial collaborations, in terms of liquidity and capacity building, between banking institutions and MFIs. For example - Barclays partnering with the

Ghana Co-operative Susu Collectors Association (GCSCA, a non-bank financial institutions' association, to supply MFIs with capital injection and wholesale funding (Fig 6.) (AAE, 2013); collaboration between EcoBank and ACCION, a global microfinancing non-profit that employs a financially-sustainable lending model (Earne, 2015); (Chu, 2006); and, Fidelity Capital's acquisition of ProCredit Savings and Loans (Agbugah, 2014). From the following examples, it can be inferred that commercial banks expanded their activities in the MF sector due to the potential profitability of micro-lending.



Fig. 6 Barclays Bank Ghana & GCSCA Partnership Model

In 2011, the Bank of Ghana issued regulatory and operational guidelines to bring varying types of MFIs under a consistent legal framework. The sophistication of the MFI sector was done by developing a tiered structure to classify MFIs according to their capital size and perceived risk to the financial stability; a licensing regime was implemented with the aim to weed out insolvent and structurally weak MFIs; subsequently, minimum capital requirements were introduced to ensure transition towards a more robust MF sector (World Bank, 2016).

Linking Microfinance Institutions (MFIs) with RE Financing

Access to modern electricity among low-income households can be greatly enhanced by enabling a robust and sophisticated microfinancing sector.

Globally, several energy-lending activities and programs related to microfinancing solar home systems (SHS) improved electricity access to rural households. For example, in 2009, a pilot project, known as Ghana Energy Development and Access Project (GEDAP), was launched to

improve energy access to households by financing the distribution of SHS with commercial loans. World Bank's Global Partnership in collaboration with the ARB Apex Bank Ltd., a government-run banking syndicate for rural MFIs, funded a solar lending project. Credit received from the World Bank aid was distributed among 12 participating MFIs. MFLs offered by the program were varied according to energy capacities and cost options. The program saw an active participation of private vendors to supply the households with the necessary hardware, installation, and further servicing of SHS. The financing conditions were tailored as – 10% down payment, and the remaining with monthly interest payments. This result-based financing program resulted in over 100,000 households benefiting from off-grid solar energy with a repayment rate of over 90%; about 93% of the clients further expressed willingness to solely pay for the costs associated with maintenance and repair (GPOBA, 2016).

Another example of microfinancing renewable energy comes from Bangladesh. Founded in 1996, Grameen Shakti, a company with the aim of providing electricity to low-income households at affordable prices. The comprehensive package offered stand-alone SHS, including a warranty of 5 years on the battery and 20 years on the panel system. In 2003, Grameen Shakti partnered with Infrastructure Development Company Limited (IDCOL), a non-bank financial institution, to bridge the financing gap for SHS deployment in low-income households (Grameen Shakti, n.d.). The financing terms entailed a loan amount of 80% of the project cost with up to 10-year maturity at 6-10% annual interest rate (IDCOL, n.d.). The results were – as of 2022, over 18million SHS deployed, benefiting more than 8million people in Bangladesh (Grameen Shakti, n.d.). The staggering success of these energy-lending programs highlights that if effective cross-sector partnerships are developed, and liquidity shortfalls in the microfinancing sector are resolved, Ghana can see a rapid mobilization of private capital towards the deployment of RE assets across the country.

Introduction to Securitization

The Subprime meltdown of 2007 gives securitization a bad name and undermines its capabilities to deploy vast amounts of capital and further democratize sector financing. In order to truly understand the potential of this financially-engineered tool to tackle financing barriers faced by RE funding, an overview of securitization theory is needed.

In the simplest term, asset securitization is a form of structured financing process where relatively homogenous cash-flow producing illiquid assets are pooled and repackaged into tradable securities and transferred to third-party investors who can now claim the impending cash-flows or any other financial benefits the pooled assets may generate (Fabozzi and Kothari, 2008). The four main phases of the securitization process include – (1) Pooling of assets (2) Transfer of pooled assets from originator to a bankruptcy-remote entity, such as a trust, or a special purpose vehicle (SPV) (3) Structuring of assets into credit pools offering varying risk/return profiles (credit enhancement) (4) Sale of securitised assets to third-party investors.



Fig. 7 Securitization Transaction Structure

A typical transaction (Fig. 7) goes as follows: a loan-originator, typically a credit institution, extends a loan to a borrower in compliance with the underwriting standards of the institution; The originator or a sponsor, typically an investment bank, creates an off-balance-sheet vehicle (OBSV), referred to as an SPV, which has a legal status of a separate corporate entity with its own balance sheet. The creation of an SPV is critical for the securitization transaction to take place. It separates the originator from the risk associated with the creditworthiness of the pooled assets, further insulating the originator from bankruptcy claims on the SPV. Another benefit of creating an SPV is that it can obtain favourable financing as its creditworthiness is solely dependent on its underlying assets and not on the financial performance of the parent company (Originator): The originator transfers the pool of assets to the SPV by means of a "true-sale," which entails that the pool of assets was legally sold, and not pledged as collateral for a financing (Fabozzi and Kothari, 2008): The SPV purchases the pooled assets from the funds received from issuance and sale of securities with varying bond classes (or tranches) to third-party investor; the following bond payments are serviced with the payments (i.e. interest and principal repayment) made by the borrower. The bond payments are made according to the varying cash distribution arrangements specific to the transactional needs.

Securitizing a pool of assets can provide various financial and legal benefits for all the parties involved in the transaction.

For the originator – due to turning on-balance-sheet financing into an off-balance sheet fee-based revenue model that is less capital intensive, originators can solely focus on lending and originating loans without assuming associated risks such as credit risk and interest rate risk. The following mechanism of transfer allows the originators to free up liquidity, as it transfers and sells

off the loan pool to a sponsor in exchange for origination fees, while at the same time retaining its capital base. Financial institutions (originators) that have the necessary infrastructure to securitize the loan pool can also retain servicing fees associated with the transaction; securitization further allows credit institutions to better manage their risk-based capital requirements – such as CAR. These regulatory requirements focus on the financial cushion, such as capital reserves of the institution and credit risk associated with the portfolio assets on the institution's balance sheet. Since securitization lowers retained risk, it enables the creation of long-term financing structures with lower capital costs to create better value for its customers (borrower).

As for the borrower – increasing credit availability in the market, as lenders now offer loans that, under normal conditions, would not have extended due to the rigidity of traditional on-balance-sheet financing. Effects of securitization trickles down in enabling access to better financing conditions – long-term maturity at lower interest rates. Finally, as the market for securitization matures, standardization of legal frameworks and transactional processes take place; this enables an increase in specialized participants competing at various stages of the transaction, encouraging price and service competition, further driving down costs for the end-user (i.e., the borrower).

Finally, for the investor – securitized assets are often tailored according to the risk-return appetite of investors, thus making the pool of assets more attractive to a wide range of retail and institutional investors. With the development of a secondary market for trading these collateralized securities, investors would benefit from improved liquidity; Further, by application of structural credit-enhancement techniques – over-collateralization, excess spread, subordination, and third-party guarantees – these securities improve their creditworthiness by offering credit support to absorb unexpected losses and risks associated with default and payment. On the demand side, this enables broadening of the investor base, as regulated credit institutions would rather prefer to buy highly accredited securities backed by loans than hold the same individual loans with a lower credit rating; Finally, securitization provides a medium for asset diversification as it enables the democratization of investment opportunities in sectors previously inaccessible to the capital markets.

From Households to the Capital Markets (Securitization of MF Loans to Enable Deployment of RE Assets)

This section focuses solely on developing a more sophisticated form of structured financing– securitization of micro-financed loans and RE equipment leases. The financing models prescribed in this chapter take key inspiration from the past securitization transactions such as – the Bangladesh Rural Advancement Committee (BRAC) USD 180million, AAA-rated securitization deal of MFLs (Rahman et al., 2007); and the Bulgarian ProCredit Bank's EUR47.8 million, BBBrated securitization deal of euro-denominated MFLs (MicroCapital, 2006). The section will recommend two key securitization models – the cross-sector partnership model and the Pay-asyou-go model.

Cross-sector Partnership (CSP) Securitization Model

This financing structure partly takes a key element of cross-sector partnership between the regional MFIs and the private solar vendors, as primarily seen in the 2009 Ghana Energy Development and Access Project (GEDAP) that oversaw massive successes in improving household energy access and overall broadening of RE market participation.

Like mortgage-backed securities (MBS), the CSP model solely relies on the interest payments and principal repayment, though it differs in underlying asset. Unlike MBS, which depend on mortgage payments, the CSP model relies on MFL repayments. The main characteristic of the model is the partnership agreement between regional MFI and individual RE systems providers (in this example, SHS providers), where these enterprises collaborate to provide financing and the technology needed to deploy solar systems for their clientele.



Fig 8. CSP Model Financial Flow Structure

Due to regulatory capital requirements and prevailing liquidity constraints, MFIs need to access capital from sophisticated financial institutions to meet credit demand. MFIs can play the part of "originator" and a "primary servicer" in the securitization process. In return for the transfer of loan obligations, commercial banks can compensate MFIs with origination and servicers fees, on top of purchase of loan obligations. As a primary servicer, MFIs maintain regular relations with the borrower – with the sole responsibility of monitoring and collecting interest payments; and in case of failure of loan repayment, recovery and disposal of collateral (i.e., solar system). MFIs have also transferred credit risk associated with the underlying loan obligations with the transfer of assets.

At the transaction pool level, the commercial banks create a reference portfolio of pooled assets acquired from MFIs and use it as collateral. The bank sets up an SPV and transfers the loan portfolio by the means of a "true" sale. SPV issues asset-backed securities (ABS) and structures them according to the seniority of claims on underlying cash-flows. Structuring of the senior-most tranche is vital for the execution of the transaction (Fabozzi and Kothari, 2008). The following tranches are structured as – senior tranche that entails the highest credit rating offering the lowest interest rate compared to other subordinated bonds; then comes the mezzanine tranche, which has a riskier position in the capital structure as compared to the senior-most tranche, though it offers a higher interest rate; and finally, the junior (equity) tranche that acts as first-loss tranche and minimizes credit risk for senior tranches. In conditions of high prepayment rates, the equity tranche absorbs the residual returns, further reducing prepayment risk for the senior tranches. Equity tranche investors receive the highest return to compensate for absorbing the highest risk in the capital structure.

Subordination structures are a widely used method of internal credit enhancement; the transaction can also implement other internal credit-enhancement mechanisms such as – excess spread, which is equal to the interest payments made by the asset portfolio minus funding costs, fees, and bond payments; the SPV can retain this excess profit by "trapping" it in a spread account to offset future losses. Overcollateralization, which is a form of equity that equals the price paid minus the par value of the collateralized assets. For example, the SPV purchase MFLs worth USD 50million and transfers USD55million to the SPV, further issuing bonds worth USD 50 million; the additional USD 5 million acts as excess collateral (Fabozzi and Kothari, 2008). Third-party financial guarantees can also be used as a form of external credit enhancement to improve the credit quality of the bond structure. Here, the government can play a big part in offering insurance support to these financial transactions.

The cash flows generated by the underlying portfolio are disbursed per the payment priority of the bondholders.

Future transactions will become cost-effective as the portfolio size increases and economies of scale are realized. Improvement in investor comfortability towards this esoteric asset class; market maturity with standardization of contracts, underwriting standards, and transactional processes; supply of reliable quality credit enhancers; and build-up of specialized competition at varying stages of the transaction will further lower costs and rates for the underlying RE assets.

Pay-as-you-go (PAYGo) Securitization Model

The PAYGo model is an innovative business model that has provided sustainable energy to households at affordable prices. The model works as follows – the energy provider rents out solar PV systems to households in exchange for monthly receivables. Due to the "no-money-down" value proposition, widespread use of mobile online payments, and falling costs of RE equipment, the PAYGo business model has seen a record-breaking sales volume of 17,000 units sold in Ghana; 27% increase in annual sales recorded in 2019 (GOGLA, 2019).

With system costs averaging at USD 15,500 per 10kW rooftop installation, few Ghanaians can afford to finance solar system installations outright (Dyson Energy, n.d.). Therefore, securitization of usage-based payment model that offers energy as a service for its consumers provides a more economical alternative



Sale of ABS

Fig 9. PAYGo Model Financial Flow

A typical securitization transaction for the PAYGo model would go as follows – A PAYGo company will buy solar PV equipment from a third-party manufacturer as per consumer demand. With installation sales, PAYGo will install, finance, and maintain the SHS for the customer in exchange for periodic payments per predetermined GH¢/kWh rate with 1-3% of annual price escalation to address the rise in electricity prices (Clark, 2014). The PAYGo company can bundle these leases and sell them to the SPV for securitization. The proceeds from the sale of underlying green-backed securities are used to purchase the bundled leases. Further recapitalization can enable PAYGo to extend its services to other households.

Securitization of these leases would have three immediate benefits to the RE industry. First, it provides PAYGo with a new means of raising capital for an asset-intense SHS installation

business, benefitting the PAYGo with recapitalization. Assuming growing demand, the PAYGo can expand lease sales to the existing portfolio for future securitization transactions. Second, the risk of default spreads among the ABS investors. Moreover finally, the development of green-ABS provides opportunities to diversify and broaden the investor base. If incentives are correctly aligned, securitization would have an additive effect on RE deployment across the nation writ large.

Ghana currently has the necessary financial infrastructure to employ securitization to develop a financing alternative for the RE industry (Asantey, 2013). Recent transactions conducted by GoG to raise capital on the international capital markets show that the concept of securitization is not foreign to Ghana. For example – Firstly, the ESLA deal, where an SPV sponsored by the GoG, E.S.L.A Plc. issued securitized bonds that denoted rights to the receivables collected from energy sector levies (E.S.L.A Plc, 2020). Finally, the Agyapa royalties deal, where the GoG created an SPV called Agyapa Royalties Ltd. and proceeded to transfer a 49% stake in Ghana's future gold royalties in perpetuity. The following deal raised USD 500 million to ease the growing debt crisis. Though the transaction was not securitized, it certainly had the building blocks of a securitization transaction (West, 2020). The following models can dramatically enhance financing practices currently employed in the RE market of Ghana.

System of Priority Sector Lending

The recommended system of Priority Sector Lending (PSL) is adopted from the playbook of the Reserve Bank of India (RBI) that mandates the banking sector to reserve and disburse at least 40% of their adjusted net bank credit of the previous year to sectors defined under the "Priority sector" category. The overarching philosophy behind mandating lending targets on financial institutions is to enable sectors of the economy that cannot receive credit either in adequate quantities or on time. PSL is synonymous with ethical financing. In India, credit institutions have made significant advancements in providing credit to green financing and social welfare (Sahoo and Goel, 2020). Under the recently revised RBI PSL guidelines, the renewable energy sector was added to the priority sector category, which enabled aligning the credit lines towards green financing. Similar to the RBI mandates, in 2015, Bangladesh Bank set up green lending requirements that dictated banks to allocate 5% of their advances into green projects (Volz, 2018). PSL guidelines and development of the RE securitization market have a synergistic effect on broadening the capital base for green financing. Debt securitization of green assets provides financial institutions with an alternative investment class to meet their PSL requirements. At the same time, further advancements in the development of a PSL framework will add to the institutional demand for PSL-asset securities. Banks prefer to invest in securitized assets that offer sufficient credit enhancement rather than risk direct exposure to underlying assets. An inpractice example that shows the synergy between the PSL framework and securitization can be seen in the Indian MBS market, where the majority of the market is driven by PSL guidelines that categorize "housing" as a priority sector for credit extension. The majority of non-banking financial institutions use securitization as a route to sell Priority sector loans to financial institutions that fall short of PSL targets (Bothra, 2014). Consequently, MBS transaction and trading volume surged to INR 950 billion as of 2018 (Sitaraman et al., 2018). From this example, it can be inferred that if appropriate regulatory frameworks are put in place, similar effects of increasing capital deployment can be seen in the renewable energy markets.

The Bank of Ghana can adopt a similar regulatory mandate of PSL that could enable sectors of the economy with the much-needed financial inclusion. Determined legislative commitment to developing both the PSL guidelines and the securitization market can greatly help prime the Ghanaian sustainable energy market.

Conclusion

Ghana, currently, is at a critical juncture for transforming its energy apparatus into a new era of sustainability. The projected rise in future energy demand, and advancements made in the energy sector debt management program, ESRP, provides Ghana with the opportunity to develop policies and strategies to guide the transition towards renewables. Although there are incentive mechanisms and regulatory frameworks in place, they have failed to actively stimulate the development of the RE apparatus. This failure may be attributed to design flaws in the policy support mechanisms, enforcement failures of the regulatory purchase compliances, weakening of price mechanisms due to failures in the implementation of co-dependent supporting policies, institutional challenges, and lack of access to domestic and international project financing markets.

Therefore, this paper has provided a critical assessment of the deficiencies in the current Ghanaian RE market and recommend alternative structures to offset the key constraints that hinder sectoral growth. The paper suggests the following strategies:

- Bundling scheme for renewable energy with conventional energy sources under current PPAs. Viability Gap Funding to bridge equity financing gaps with auctioned government grants.
- Tax-equity structures such as partnership flip to incentivize institutional project equity participation.
- Development of financially-engineered tools such as securitization of microfinance loans to lower risk and cost of capital for off-grid renewable systems.
- Adoption of Priority-sector lending framework to mandate institutional lending advances towards the RE sector.

In conclusion, Ghana must pursue appropriate and actionable strategies in order to achieve its SDG 7 targets. It must be noted that no amount of financial and regulatory innovation can deter risks involved with an uncommitted government. Therefore, it is of utmost importance that regulatory commitment goes hand-in-hand with private RE sector advancements to expedite the acceleration of renewable energy development in the country.

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