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

Priyanka Prem Kumar, Ankur Rangi, and Anirban Roy (AI for Rural, India)

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

GoI………………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.

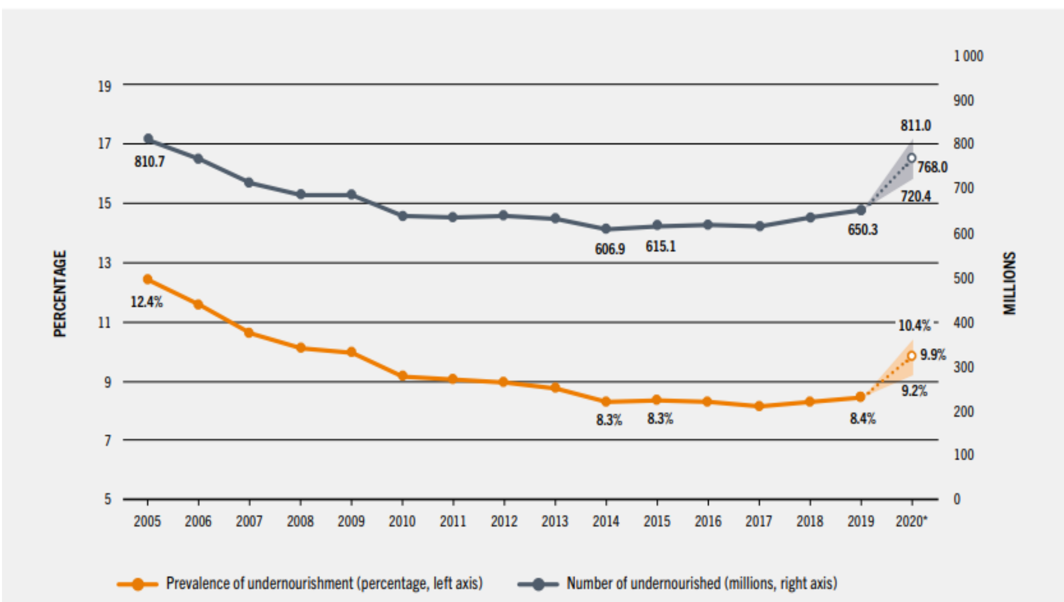

Figure 1: The number of undernourished people in the world continued to rise in 2020

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.

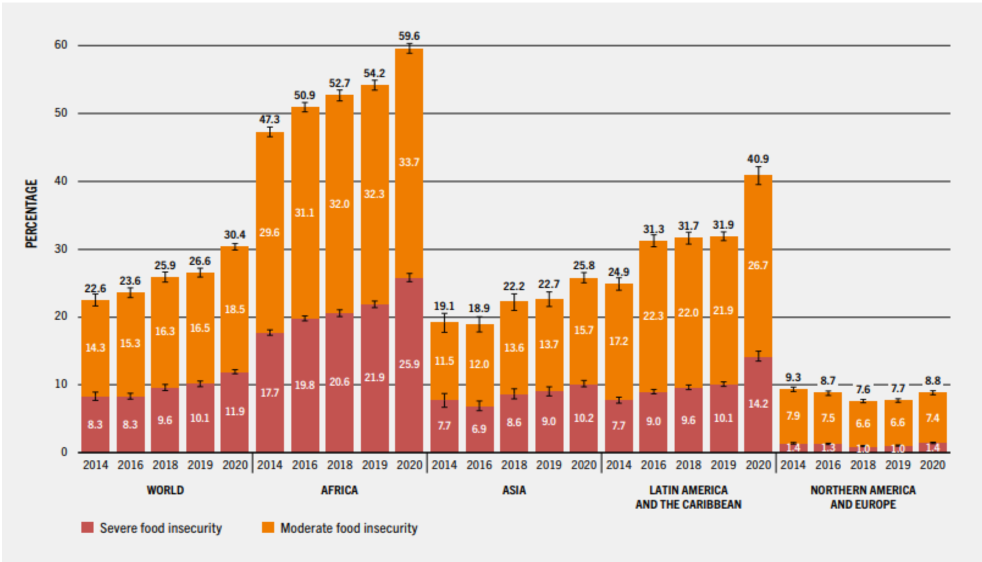

Figure 2: Moderate or severe food insecurity has been climbing slowly for six years

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 ≥ 2°
- 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.

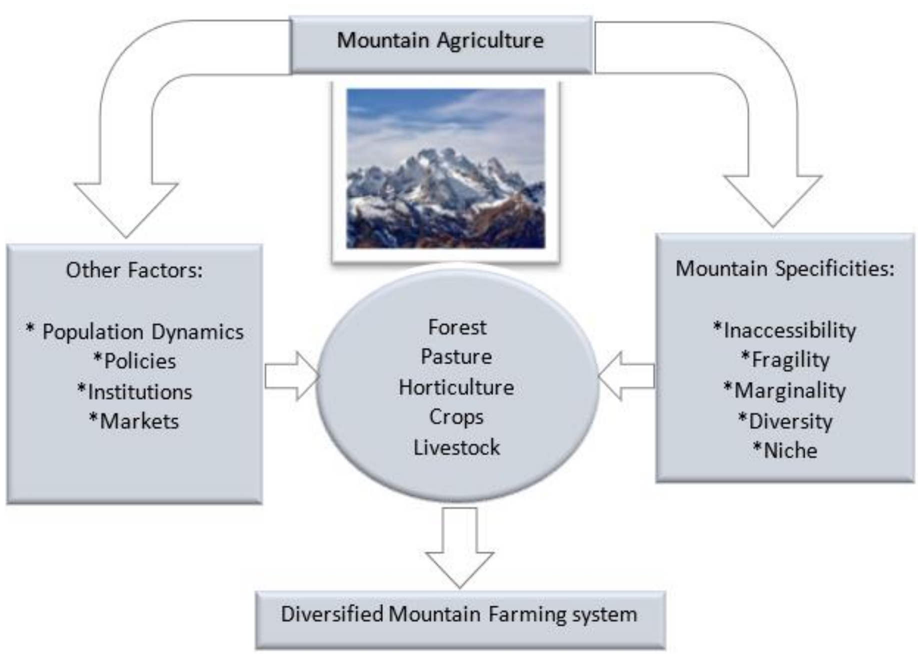

Figure 3: Mountain Agricultural System

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 AI 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 Aayog 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.

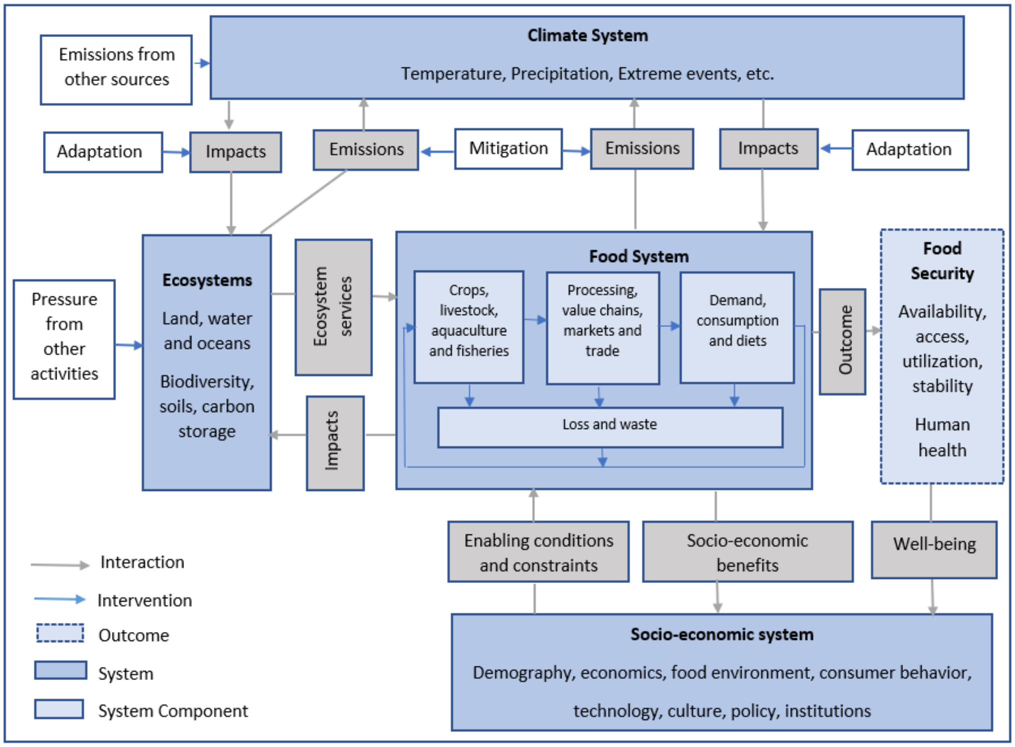

Figure 4: Interlinkages between the climate system, food system, and socio-economic system

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 resilience-building 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.

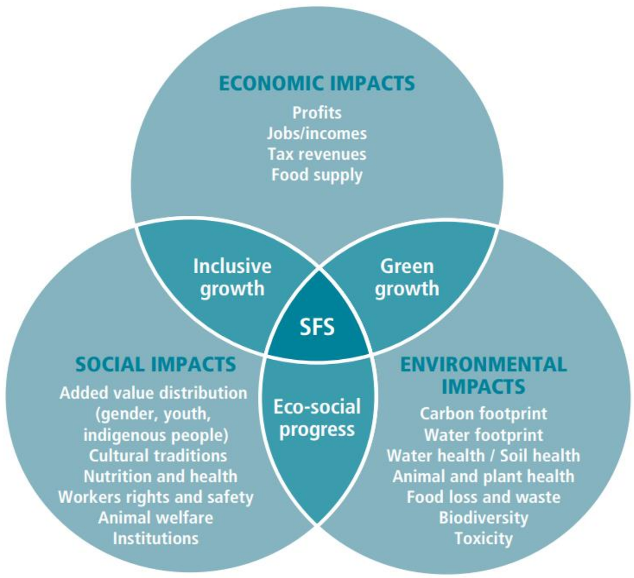

Figure 6: Sustainability in Food systems

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.

AI 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.

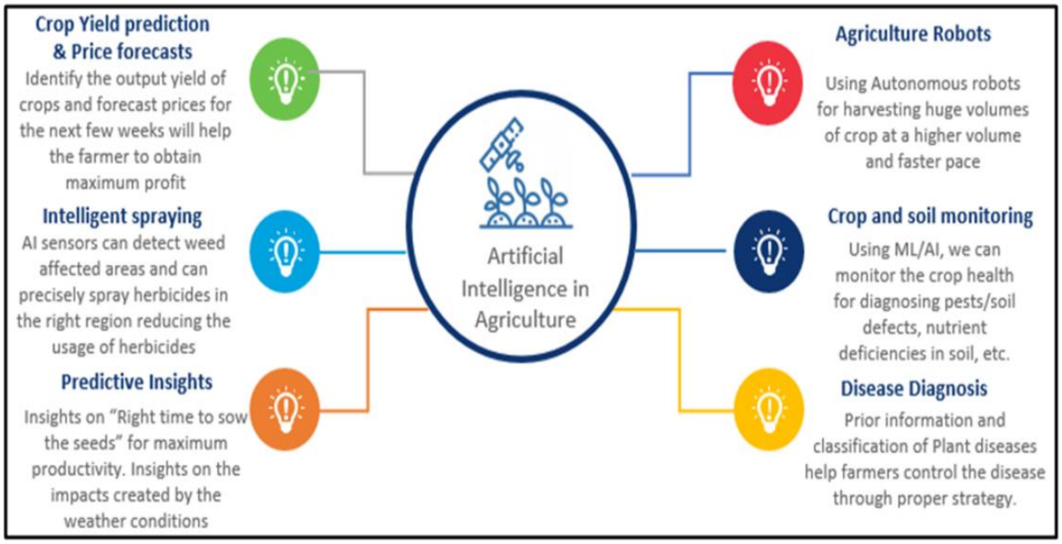

Figure 7: AI in Agriculture

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.
- AI 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.
- AI 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.
- AI 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.

- AI 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.

- AI 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.

- AI 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

Table 1: Agricultural Production (Rice) in 2020

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

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.

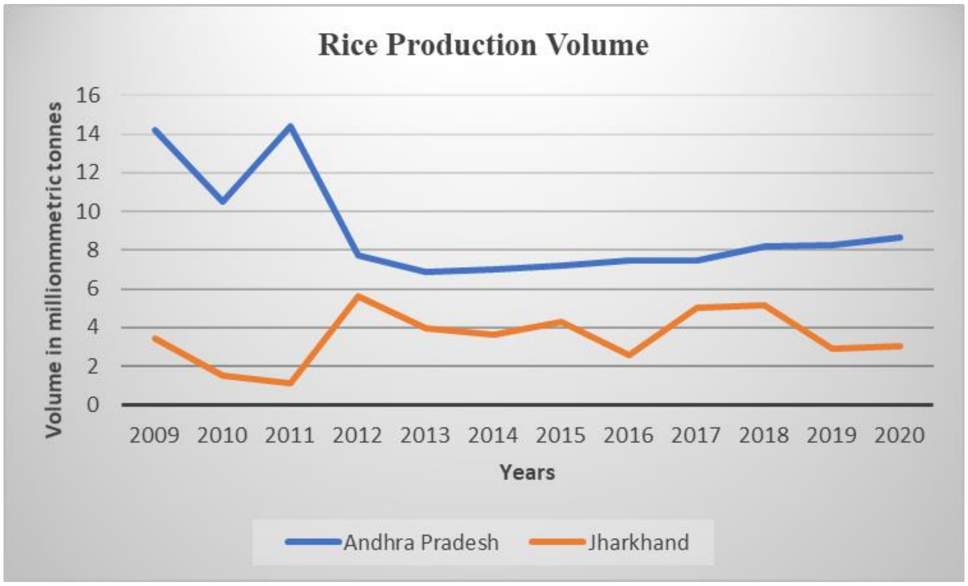

Figure 8: Volume of Rice production across Andhra and Jharkhand from the Financial year 2009 to 2020

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.

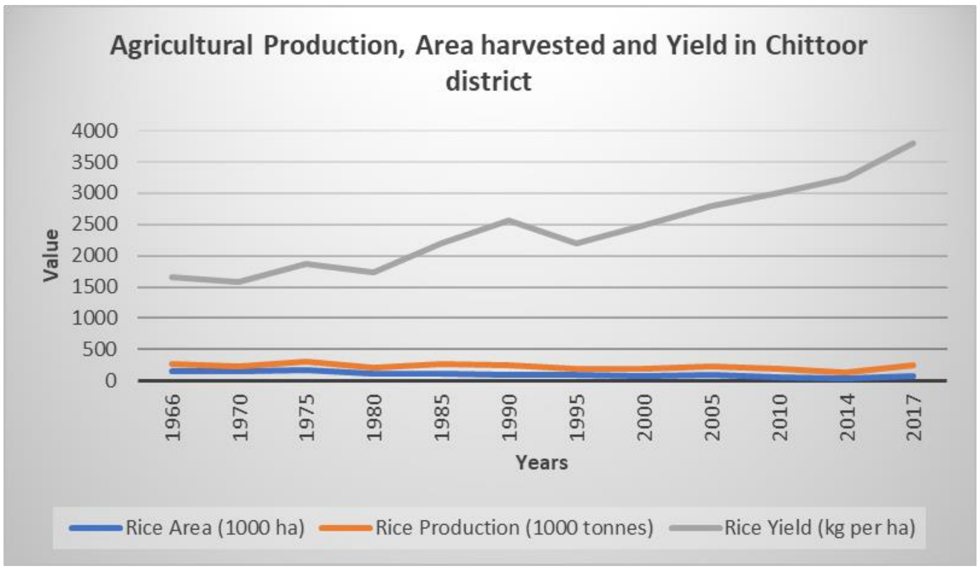

Figure 9: Agricultural Production, Area Harvested, and Yield (Rice) in Chittoor District

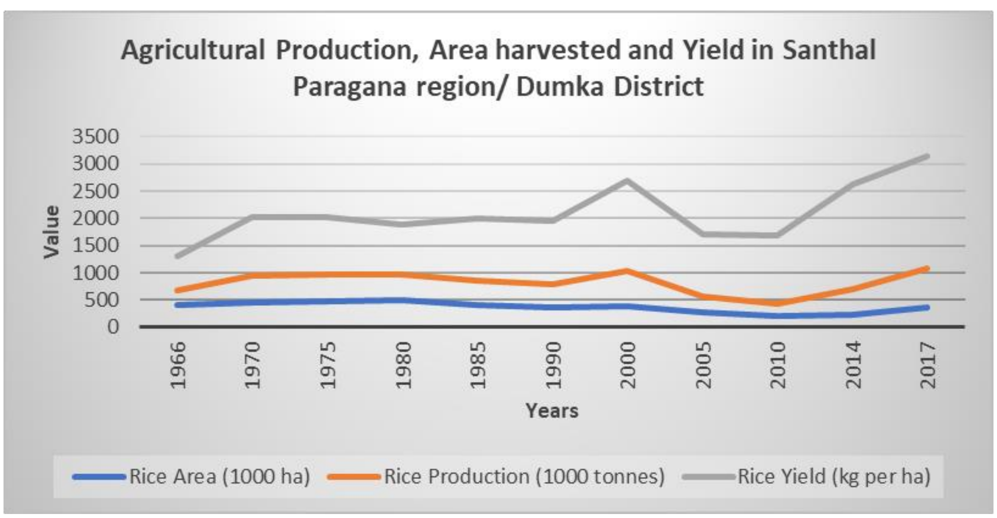

Figure 10: Agricultural Production, Area Harvested, and Yield (Rice) in Dumka District

Weather Statistics for Farming

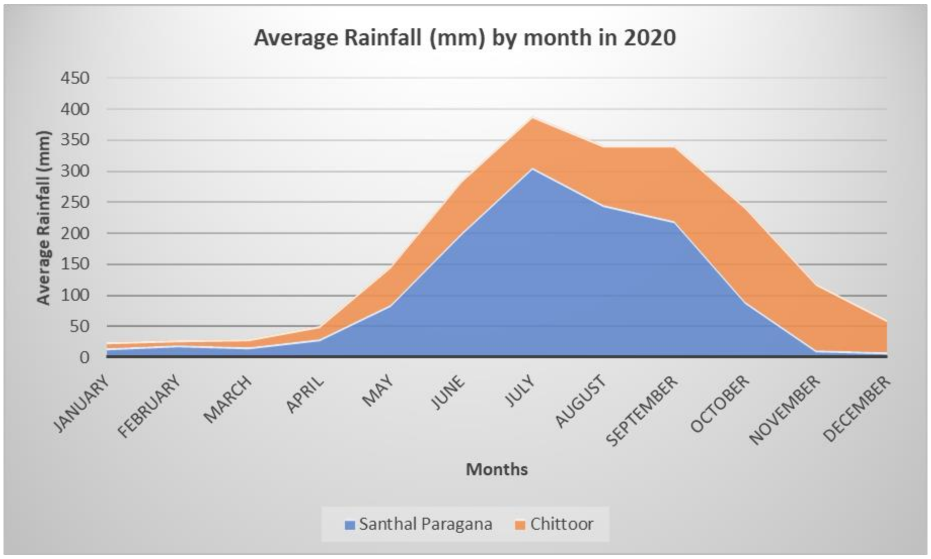

Figure 11: Average Rainfall (mm) by month in Santhal Paragana and Chittoor region

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 figure11.

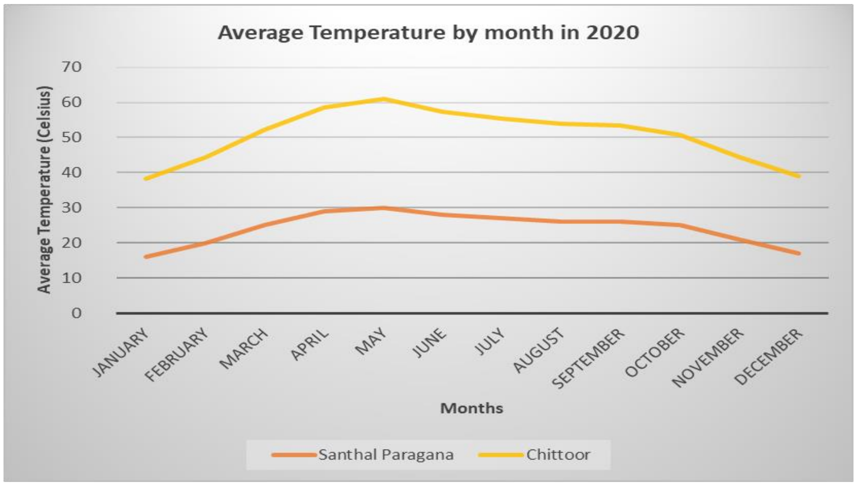

Figure 12: Average temperature around the year in Santhal Pargana and Chittoor District

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.

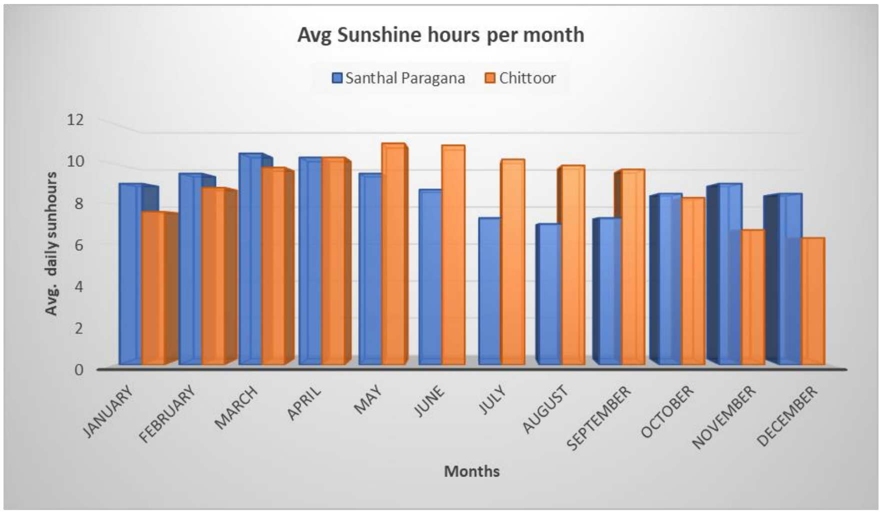

Figure 13: Average daily Sunshine hours per month in Santhal Pargana and Chittoor

Table 2: Weather by Month (Average) in Santhal Pargana Region

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature °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 / Rainfall mm (in)	17	21	19	26	86	201	306	246	223	88	12	8
	-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.	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

Avg. Temperature °C (°F)	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 / Rainfall mm (in)	9	7	13	21	62	85	83	96	121	153	107	52
	-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 (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.

Table 4: Proposition of Bank Branches by Type of Banks

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

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,

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 and Credit of the Banks as of 31st 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	18617 8	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 GoI. 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 GoI 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 GoI 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 large-scale 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 available in the market for farming. To ensure that technology reaches everyone, solutions must become more accessible, like in an open-source platform where solutions are more economical and quickly embraced by farmers.

AI 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

AI 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.

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