Partnering to Maximize the Impact of Technological Innovation in Postharvest Processes in Rural Areas

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Abstract

Postharvest losses are high in the rural areas of sub-Saharan Africa due to poor road infrastructure and lack of appropriate technologies. This paper reports the use of appropriate technologies to curb poverty and hunger in the rural areas of sub-Saharan Africa due to poor postharvest processes by farmers and how to explore appropriate partnerships to enhance the impacts of the technological innovation. The technologies developed is a drone for data gathering and a new multi-crop drying machine composed of a drying chamber with one end having a heat collector essentially a black body and the other end suction fans to enable circulation of hot dry air. The use of the machine in postharvest processes prevents rapid degradation of farm produce before delivery to urban markets due to poor road infrastructure. The area of implementation of the technological innovation is the kupe-manegouba division in Cameroon due to its enclaved nature with less than 10 kilometres of tarred road. Statistics from the divisional delegation of agriculture show that postharvest losses for plantains is 35%. This percentage could be higher if not of traders who exploit farmers by buying their produce at giving away prices of 200FCFA per bunch to sell later at 5000FCFA. Such practice will enhance poverty and hunger for the local farmers. With the implementation of the technologies and local partnerships, the postharvest losses were reduced to 28.6% and it is envisaged that, with broad-based partnerships, the postharvest losses could be further reduced to less than 5% by 2030.

Keywords: postharvest; multi-crop machine; drone; innovation; partnership; farmers.

Purpose

Partnerships are essential for the achievement of the Sustainable Development Goals (SDGs) and the United Nations transformational agenda for 2030. Only through close collaboration can there be any possibility of finding global solutions to the world’s current and future challenges. This paper presents the technological innovation of the College of Technology of the University of Buea, Cameroon in postharvest process in rural areas and how the College of Technology has sought public, public-private, and civil society partnerships to maximize the impact of the innovation. Postharvest processes present a major challenge in rural areas in sub-Saharan Africa because of rapid degradation of farm produce before delivery to urban markets due to poor road infrastructure.

Traditional attempts through partnerships to improve the incomes of smallholder farmers, hence enhancing productivity in sub-Saharan Africa have focused on increased access to improved seeds, irrigation technology, fertilizers, pesticides, agronomic training, and financial services. However, these attempts enhance crop production and does not adequately address efficient postharvest handling and delivery to urban areas due to poor road infrastructure. In the absence of adequate infrastructure, sustainable developmental efforts and partnerships driven by technological innovation could unleash dynamic and competitive economic forces that generate employment and income, hence reducing inequalities (Vegah and Sone, 2019).

In this light, valuable partnerships have been established by the College of Technology with the Southwest Development Authority (SOWEDA), community centres and farmers' cooperatives and delegations / sub-delegations of the ministry of agriculture notably in the kupe-manegouba division of the Republic of Cameroon and a financial institution in Bangem, the capital of the kupe-manegouba division.

The technological innovation matters because it improves the lives of everyone most especially the farmers in the rural areas confronted with the challenge of poor postharvest processes. The innovation is based on a sustainable multifunction machine used for tropical agric products processes (Wei et al, 2018), with the aim of minimizing postharvest losses coupled with a drone system which ensures information gathering (Colimina and Molina, 2014; Dji, 2021).

The innovation has a substantial impact on some SDGs notably no poverty and zero hunger since it addressed the main challenge faced by farmers in Cameroon, West Africa, and the sub-Sahara African region, namely, the lack of techniques and appropriate equipment for postharvest activities. A variety of farm produce could be appropriately dried by the novel machine for long periods sufficient to reach the main markets.

Statistics from the divisional delegation of agriculture show that the following agricultural commodities are cultivated in the kupe-manegouba division: cassava, cocoyam, plantains, maize, pepper, irish potatoes, beans, cabbages, tomatoes, palm oil, coffee, cocoa. The total surface area used is 13063 hectares for a total per annum production of 3913982 tons with plantains constituting the bulk of the production with 3900000 tons. Such a production potential for a division with less than one hundred and fifty thousand inhabitants is adequate to ensure zero hunger and no poverty to inhabitants in the division and beyond. However, the prevailing situation is appalling due to poor road infrastructure and poor postharvest handling practices. Due to poor postharvest practices, the postharvest loss for the agricultural commodities is enormous ranging from 15% for cabbages to 40% for irish potatoes. The percentage loss for plantains stands at 35% implying that 1365000 tons of plantains are lost annually. Hence, a fraction of the population of the division and beyond is deprived of the valuable commodity resulting to hunger. The postharvest loss could be higher if not of traders who exploit farmers by buying their produce at giving away prices of say 200FCFA per bunch of plantains to sell later at 5000FCFA. Such practice will enhance poverty for the local farmers with its accompanying effects such as lack of money to ensure balanced diet and to provide adequate medical care. With the implementation of the technological innovation by the College of Technology of the University of Buea which involves modern data gathering techniques using locally made drone and a multi-crop drying machine for postharvest handling, the postharvest losses are reduced considerably. The impact of this technological innovation is enhanced through valuable partnerships with local stakeholders such as the mayor of Bangem who provided funds for the purchase of the machine while the participating farmers paid a minimal sum of money for the maintenance of the machine. The technology was implemented in one of the villages of the Bangem sub-division for some selected farmers. The agricultural commodities processed were plantains, maize, pepper, irish potatoes, tomatoes, cocoa. The postharvest losses for these commodities reduced drastically, for example we recorded a postharvest loss for plantains of 19% as compared to 35% initially for the group of selected twenty (20) farmers. However, the total postharvest loss for the entire division did not change significantly with that of plantains being 32.84% since most of the farmers and agricultural commodities could not be covered due to lack of funds. The College of Technology envisage to establish broad-based partnerships with national and international stakeholders to increase the level of coverage to reduce postharvest losses to less than 5% by 2030 for all the agricultural commodities in the kupe-manegouba division and beyond. Such actions will ensure the drastic reduction of poverty and hunger in Cameroon and the Central Africa sub-region considering the role Cameroon plays in the sub-region (Vinicuis and Leonardo, 2009).

The complete outline of the paper is as follows. In the next section, a methodology to improve postharvest processes using a multi-crop drying machine and a drone is presented. In the first part, the design of the multi-crop drying machine is presented while the second part presents the design of the drone used for data gathering in remote areas. The section concludes with the step-by-step methodology known as “The Commodity Systems Assessment Methodology (CSAM)” conceived and initiated by Harvey Neese to enhance productivity by associating partners with the innovative technology. Results and performance analysis of the innovative technology in postharvest processes will be presented in section 3. Finally, the conclusion and recommendations are presented in section 4.

Methodology

This section presents the methodology used to improve postharvest processes using the multi-crop drying machine and the drone. In addition, the approach to be adopted based on the statistics from the divisional delegation to seek for partnerships will be explored (Pravalika and Aditya, 2021; Silveira *et al.*, 2018; Tian *et al.*, 2018).

Design of Multi-crop Drying Machine

Design Criteria

The following design criteria is used in the production of the machine (Norton, 1992; Franco *et al.*, 2018; Mobey *et al.*, 2020; Karunaraja, *et al.*, 2015):

- The machine can save fuel and electricity and drying time in solar dryer is reduced in comparison to open drying method.

- Products must be protected against flies, rain, and dust.

- The dryers are waterproof, so produce can be left in the dryer overnight during rain.
- The design is scalable, such that the machines can be connected in parallel.
- It can be dismantled easily for easy maintenance or allow easy transportation from one place to another.
- Drying is also carried out at night using stored heat energy, collected during the daytime and with electric heaters located at the optimal position in the drying chamber.
- Materials required for fabrication of solar dryer are locally available.

Description of the Machine

In this section, the description of the multi-crop drying machine is presented. The specification of the machine is presented followed by the prototype. The section concludes with the improvements on the prototype based on field experience of the initial prototype, clearly indicating the reasons for the improvement and the conditions after the improvement.

Specification

The technological innovation project is based on a sustainable multifunction machine used for tropical agricultural products processes, to minimize postharvest losses (Lokesh et al., 2015; Patchimanpom *et al.*, 2020; Srinivasan, Rabha and Muthukumar, 2021). The system consists of a parabolic collector, Arduino microcontroller, and a drying chamber. The dryer is operated during normal sunny days as a solar dryer and as a hybrid solar dryer during cloudy days. The machine is composed of a drying chamber with one end of the chamber having a heat collector which is essentially a black body and the other end having suction fans to enable circulation of hot dry air in the chamber. The heat collector comprises a parabolic reflector and a cylindrical black body. Sun rays are reflected from the parabolic reflector onto the black body with the highly concentrated heat transmitted to the drying chamber through the black body cylinder. The kernel component is a microcontroller that reads the sensor and controls the outputs such as humidity, fan, and motor of the crop shuffling system (Ntwali et al., 2021; Puello-Mendeza et al., 2017; Pravalika and Aditya, 2021).

Initial Prototype

The drying chamber comprises the following features:

- An insulated metal box with a capacity of 15 liters of crop per batch; volume of 275l.
- Weight of chain drive locally of 20kg.

- Volume of feeder Hopper of 50 liters.
- Weight of the stand is 33kg.
- A 20-rpm motor.
- Width of the drying chamber is 1 meter, and the length is 2 meters.
- Heat collector system is 3 meters long.
- The total weight of the machine is 70 kg.

The following reasons guided the choice of the above features:

- The conveyor belts are made up of a filter cloth and are used to enable a clear spread and shuffling of the agricultural commodity.
- The weight of the feeder shaft and conveyor belt rolling system was taken into consideration in the mathematical modelling such that, the torque to be generated by the electric motor could counterbalance the external mechanical actions exerted on the upper feeder shaft free body diagram during the feeding process (Tsamo Toko and Talla., 2020; Qiang Paulo and Hamid, 2017).
- The manufacturability of the workpieces was considered when designing shape, aesthetics and the topography of the new multi-crop drying machine.
- The size and the volume of the system are in such a way that it can be transportable on a standard four-wheel driver pickup to easily reach the operating area (Ngale and Tsamo, 2016).
- Suitable static seals to ensure the static sealing between the upper part and the drying chamber.
- Suitable dynamic seals (Paultra double leaves seals) to ensure the dynamic sealing between the feeder shaft and the frame, and between the conveyor belt shafts and the frame.

The design structure was built with SOLIDWORKS. Figure 1 shows the chamber design with the layout of the conveyor belts while figure 2 shows the chamber prototype. The initial machine prototype is shown in figure 3.

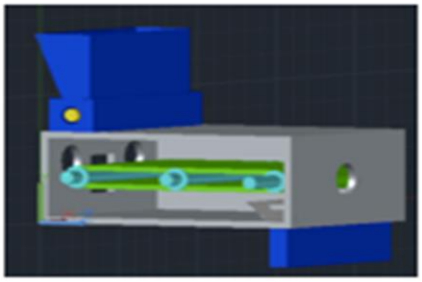

Figure 1: Chamber Design

Figure 2: Chamber prototype

Figure 3: Initial Machine Prototype

Improved Prototype

After initial trials in the field, certain features of the machine prototype in figure 3 were improved upon. The features are:

- Integrated system, made up of mechanical, electrical, electronic, and computing components, which are interconnected. The mechanical system is made of several components, whose main parts are the feeder system, the drying chamber, the heat collector assembly, the unloading mechanism, and the frame.

- The feeding shaft is guided by four (4) auto lubricated ball bearings SKF NF 3206 to reduce the friction between the feeding shaft and the upper frame.

- The conveyor belt shafts, or the rotating drying chamber are guided in rotation by four (4) auto lubricated ball bearings SKF 3307, to reduce the friction between the conveyor's rollers and the lower frame (Giang et al.,2017).

- Standardized fasteners are used for interchangeability and easy maintenance.

- To ensure strong reliability of the main parts of the machine, the value of the safety factor used in the design of machine elements is equal to 2.5 (Bazergui et al.,1985).

- The Tresca yield criterion on the Hookean material models is used to obtain some optimal design variables such as feeder minimum shaft diameter (ϕ30 mm) and conveyor belts rollers minimum diameter (ϕ32 mm) (Chields, 2004; Ngale & Tsamo, 2016).

- The suitable choice of the fit between the feeder shaft and the feeder sprocket is ϕ 30H7e8. The fit between the conveyor belt rollers and the conveyor belt shaft sprockets is ϕ32H7e8.

The reasons for the improved prototype are as follows:

- The system was adjusted to be user friendly by introducing an easy-to-operate dashboard. This ensures that, a farmer with very poor skills can operate the machine and be able to carry out basic operations of drying and maintenance. This is essential since the farmers in the rural areas are not generally exposed to such technologies.

- The use of standard elements such as; bearings, static and dynamic seals, nuts with ISO pitch, keys, washers, and commercial fasteners will considerably reduce the production cost of the machine.

- The Tresca yield criterion was used since the stress generated inside the feeder shaft and the conveyor belt rollers is less than the material yield strength used, due to the low working speed of the shafts.

- The fit is such that, the setting of the appropriate geometrical tolerances at the drafting office on the workpiece drawing will lead to a long-life span of the machine.

The conditions after the improvement are such that, there is a shorter drying time, long-life span and improved drying capacity during the rainy season.

AI Model and Drone Implementation

A lot is happening lately about drone applications in agriculture and precision farming (Kulbacki *et al.*, 2018; Hassanalian and Abdelkefi, 2017). From the ability to image, recreate and analyze individual leaves on a corn plant from 120 meters height, to getting information on the waterholding capacity of soils to variable-rate water applications, agricultural practices are changing due to drones delivering agricultural intelligence for both farmers and agricultural consultants (Veroustraete, 2015; Li *et al*, 2009).

Simply having an aerial imagery tool is not enough to monitor agriculturally based projects for professionals who are in the quest for production yield. A model to watch the growth and alert the owner of exploitation must be attached to the drone (Colwell, 1956; DJI Official, 2021, Gupta, Ghonge, and Jawandhiya, 2013; Guo et al, 2013). Our proposal is therefore subdivided in two parts, namely AI model implementation and drone implementation.

AI Model Implementation

Several Machine Learning environments are easily available on the internet that does not need any system specification or framework specifications and use cloud technology to train the model in the best possible time. Some of these open-source machine learning environments such as Google Colaboratory, Kaggle Kernal , are excellent platforms for deep learning and machine learning applications in the cloud (Riturajsaha, 2021). They are google products and require the knowledge of data science in order to develop a model to be fitted in a production environment (Milanova, 2018). The model generated should be able to generate classes to classify crops detected from image analysis (Guo *et al.*, 2016) and detect crop diseases (Tchito *et al*., 2021). However, the technique used in our implementation is the Google's Teachable Machine which Google introduced as a new open-source platform for training machine learning models that developers could use to code as shown in figure 4.

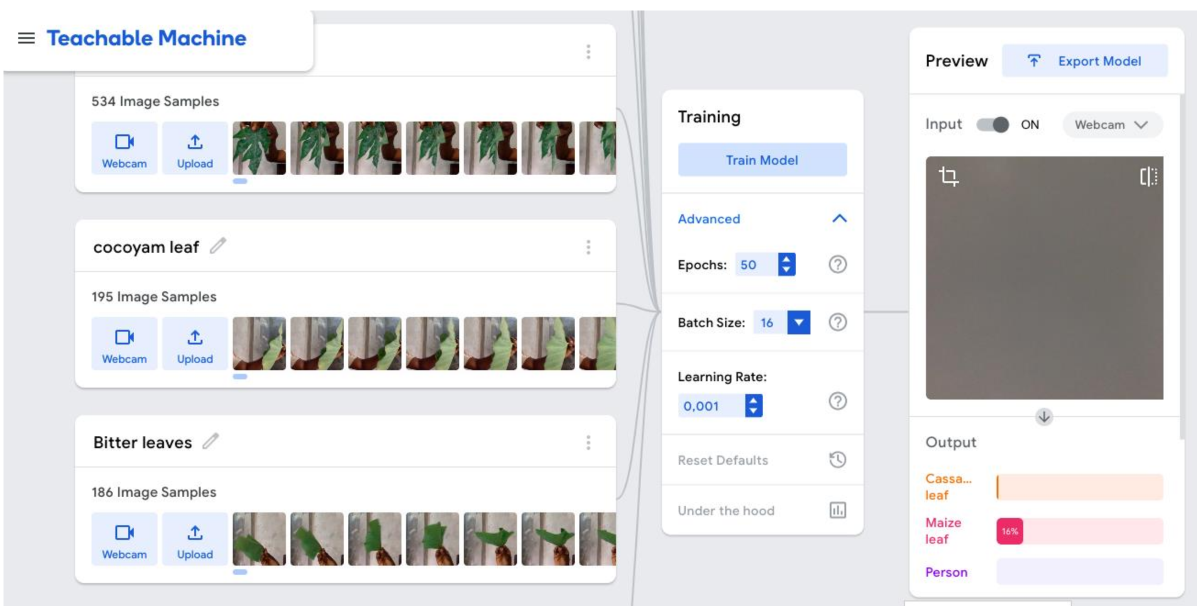

Figure 4: Teachable Machine Environment

The technique used in this machine environment is supervised learning, meaning that the model will be generated from a set of available data. The accuracy of that model will depend on the learning which will be quantified from error on prediction symbolized by the loss, and yield that emanates from the testing with the unseen data.

The implementation of the model is based on a series of pictures captured to establish the dataset. Teachable machine subdivides the dataset in two bunches. The first bunch, made up of 85% of the dataset, represents the training set and the rest of 15% represents the testing set. Figure 5 shows some samples taken, to recognize some cassava leaves in our model, out of 231 images just for that class.

Figure 5: Collection of leaf samples

Our machine is customized for a learning rate of 0.01, for 16 Batches of 50 epochs, and results depicted in table 1 show an accuracy of 100% for crop leaf considered.

Table 1: Accuracy per Class

CLASS	ACCURACY	# SAMPLES
Cassava leaf	1.00	35
Maize leaf	1.00	32
Person	1.00	15
plantain Leaf	1.00	77
pawpaw leaf	1.00	81
cocoyam leaf	1.00	30
Bitter leaves	1.00	28
EMPTY	1.00	3

The confusion matrix in figure 6 represents how well, the model predict data left out for the testing set. In the Y axis we have the class concerned, and in the x axis we have the corresponding value obtained from the model

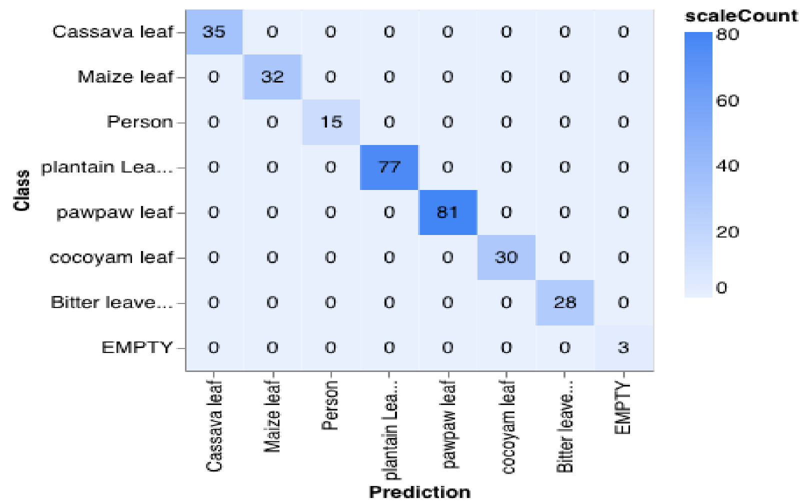

Figure 6: Confusion Matrix

Accuracy is the percentage of classification that the model gets right during the training, as presented in figure 7-b and it's shown that 100% is reached before the first 10 Epochs. Loss is a measure to evaluate how well the model has learned to predict the right classification for a given dataset.

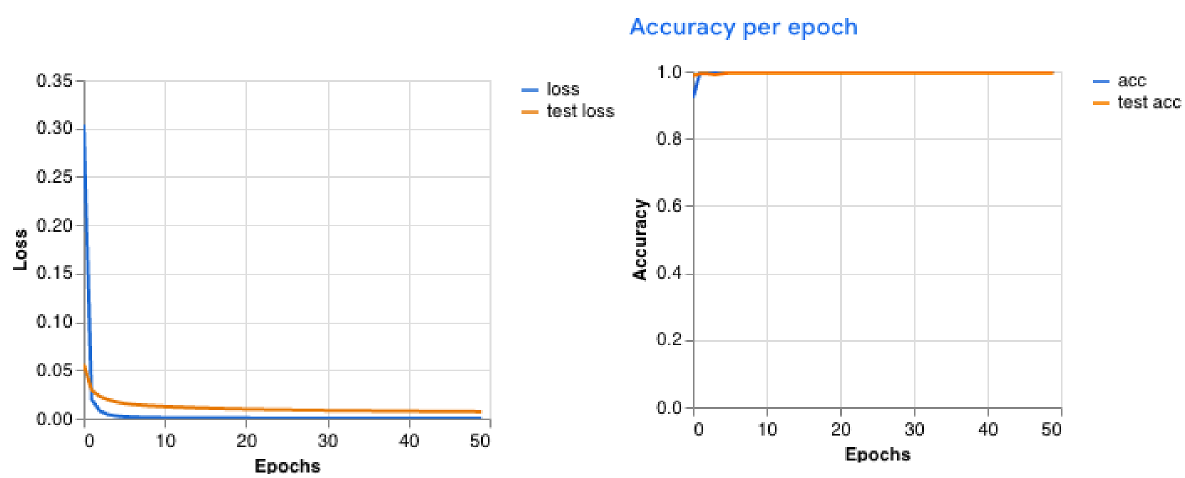

Figure 7: Loss and accuracy of the model. a) Loss per epoch; b) Accuracy per epoch

Drone Implementation

Over time, drones have increased in capabilities and fallen in cost, and their use has greatly expanded especially in complex terrain. High quality remote sensing with spectral imaging using drones makes them interesting for regular use in Precision Agriculture (PA) (Kulbacki *et al.*, 2018; Hassanalian and Abdelkefi, 2017). Drones are often used in agriculture in ways that were highly controversial only a short time ago since there is no unified legislation on drones usage in agriculture.

First remote sensing usage for precise measurements of cropland have been documented in 1930s and practically applied since 1950s. Since then, satellites have been scanning the earth and crops and measuring spectral reflectance properties and temperature crucial for farmers. The temperature indicates whether the crop is healthy. Currently by processing satellites data into evapotranspiration images one can gather information about, how much carbon is taken, how much water is used on individual fields and even predict how much water is being used by a certain field or a certain product (Li *et al.*, 2009). Most of the farmers in the world especially in sub-Saharan Africa cannot effectively use this information (Kulbacki *et al.*, 2018). Figure 8 shows a 3d printed drone's frame and drone prototype.

Figure 8: Drone Implementation, a) 3d Printed Drone's Frame; b) Drone prototype

Drone's Characteristics are:

- Transmission distance: 3Km
- Flying Autonomy: 40 minutes flight time with 500mAH battery capacity

Exploring the Cropland with the Equipped Multispectral Camera

The multispectral camera will be incorporated in our design to consolidate the data extraction process and gain insights into crop health/vegetation management by considering the following camera features (Dji, 2021):

- Imagery: there are six individual lenses. 1 RGB camera and a multispectral camera array with 5 cameras covering Blue, Green, Red, Red Edge, and Near Infrared bands. The five-band multispectral camera can be used to assess Normalized Difference Vegetation Index (NDVI), Normalized Difference Red Edge (NDRE), Modified Soil Adjusted Vegetation Index (MSAVI) and many other formulas for vegetation analysis. NDVI is an indicator of a plant's health based on how it reflects light waves. The one with a lot of chlorophyll and good cell structure actively absorbs red light (RED) and reflects near infrared (NIR). And exactly the opposite happens to a diseased plant. NDRE is a method of measuring the amount of chlorophyll in the plants. The best timing to apply NDRE is mid-to-late growing season when the plants are mature and ready to be harvested. At this point, other indices would be less effective to use MSAVI works where other vegetation indices do not. During seed germination and leaf development stages, MSAVI can be used on Crop Monitoring to monitor seedlings when there is a lot of bare soil in the field. All at 2 Mega Pixels (MP) with global shutter, on a 3-axis stabilized gimbal.

- Sunlight sensor: an integrated spectral sunlight sensor sits on top of the drone to capture solar irradiance. This increases data collection consistency throughout the day & helps obtain the most accurate NDVI results.

- Red Green Blue (RGB) & NDVI: you can easily switch between a preliminary NDVI analysis and the live RGB feed to instantly see where attention is needed so that you can make targeted treatment decisions efficiently.

- Centimetre precision: Drone's Time Synchronization (TimeSync) system means you get real-time, accurate positioning data on images captured by all six cameras, providing centimetre-level accurate measurements. The TimeSync system continually aligns the flight controller, RGB and NB (Near Infrared, Blue) cameras, and Real Time Kinematic (RTK) module. They help in fixing the positioning data to the centre of the Complementary Metal Oxide Semiconductor (CMOS) used to create images in digital cameras) sensor and ensuring each photo uses the most accurate metadata.

- Mobile Application (Android/IOS): one of the standout features of our drone is ability to plan intelligent agriculture missions. Plan flights, execute automated missions and manage flight data using drone's leading flight planning Android/iOS app. The app has an intuitive, easy to use interface. With data collected and analyzed it's easy to take action.

- Switch between a preliminary NDVI analysis and the live RGB feed to immediately visualize where attention is needed, so that targeted treatment decisions can be made quickly, but also accurate decisions concerning the harvesting could be made using the multispectral camera.

Using NDVI, NDRE and MSAVI pictures filters combined with post-flight image processing to create a weed map, farmers and their agronomists can easily differentiate areas of high intensity weed proliferation from healthy crop areas growing right alongside them. Historically, many farmers haven't realized how pronounced their weed problem is until harvesting was performed. Figure 9 shows the farm view through the multispectral camera for both RGB and NDVI feeds.

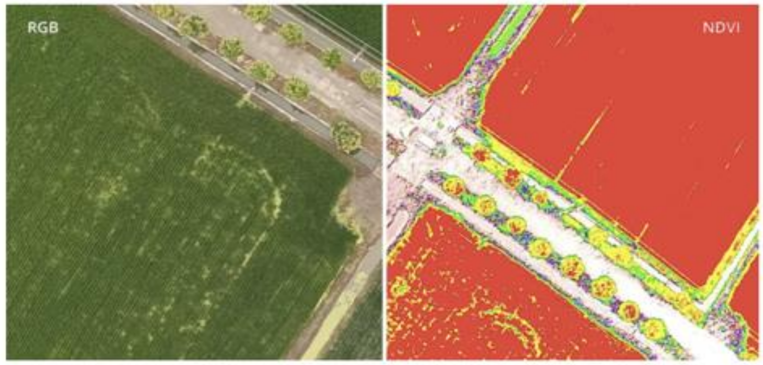

Figure 9: Farm View through Multispectral Camera, a)RGB; b) NDVI

Another important feature of the multispectral camera is the centimeter-level precision. This entails obtaining real-time, accurate positioning data on images captured by six cameras with DJI's TimeSync system with centimeter-level accurate measurements.

Step-by-step Methodology

The methodology adopted in our work is a step-by-step methodology known as "The Commodity Systems Assessment Methodology (CSAM)" conceived and initiated by Harvey Neese, Director of the Postharvest Institute for Perishables (PIP) (Harvey et al. 2013). Implementing CSAM results in the identification of priority problems in the commodity system and defining possible solutions. In our work, a 4-step solution to solve food problems currently and in the future include data gathering, postharvest handling, marketing of the agricultural commodities and sensitization of the farmers on the use of the innovative technology and government officials through the participation in national events.

In step 1, the drone is used to collect data of farm produce in the rural areas. The drone is launched from the divisional headquarters of Bangem in the Kupe-manegouba division of the Republic of Cameroon. The drone monitors the growth of the crops including cases of pest attacks. The data is collated with our government partners at the divisional delegation of agriculture of Kupe-manegouba division. In the case of normal crop growth, the data collected will indicate the appropriate period to start the postharvest handling using the multi-crop drying machine. However, for abnormal crop growth due to pest as detected by the drone, the farmers are assisted with a soft loan by our financial partner. The microfinance institution based in Bangem offers pesticides to the farmers with equivalent cash worth retrieved after sales of the farm produce. During this step, the Southwest Development Authority (SOWEDA) ensures the sensitization and technical assistance of the farmers and the cooperatives.

In step 2, the multi-crop drying machine is used for postharvest handling. The machine is placed at the village square for use by a group of farmers. Provision is made for a warehouse to store the processed products and the farmers are educated on the functioning of the machine by a

facilitator. The mayor of Bangem provided funds for the purchase of the machine while the participating farmers are charged a minimal sum of money for the maintenance of the machine.
In step 3 which involves the marketing of the agricultural commodities, a partner financial institution based in Bangem acts as a facilitator. The microfinance institution called "Nninong Bangem Better Life Microfinance (NIBABLIFE)" ensures the sales of the commodities in urban markets on behalf of the farmers. This action greatly reduces the role of middlemen in the entire market chain. With middlemen, the commodities such as plantains were bought at two hundred francs CFA (200FCFA) and sold at five thousand francs CFA (5000FCFA). With the actions of NIBABLIFE, the farmers have full value of their proceeds and are sensitized on the advantages of saving part of their earnings.

In step 4 which involves sensitization of the farmers on the use of the innovative technology and government officials through the participation in national events, the College of Technology of the University of Buea has participated in the annual agropastoral shows organized by the southwest regional delegation of agriculture and rural development in Buea. During this occasion, the College of Technology showcased the innovative technology to visiting farmers and cooperatives. In addition, the College of Technology has participated in major national events organized by the government of Cameroon on technological innovation. In 2019, the event was organized by the ministry of higher of education in Maroua in the far north region of Cameroon in the sidelines of the university games. The College emerged with the first prize by exhibiting the novel multi-crop drying machine. Figure 10 (a) shows our students during the competition. In 2021, a national event on technological innovation was organized in Douala and the College of Technology emerged with the first prize by exhibiting the novel drone technology. Figure 10 (b) shows the students during the competition.

Figure 10: a) Students in Maroua b) Students in Douala

Findings

Our findings are based on the statistics of losses of agricultural commodities obtained from the divisional delegation of agriculture of kupe-manegouba division. These statistics will be compared to losses of some commodities after the implementation of the technological innovation and existing partnerships on some selected twenty (20) farmers. Finally, the losses will be projected for the case of broad-based partnerships through the year 2030.

Choice of Farmers

The kupe-manegouba division of the Republic of Cameroon has a population of 106.000 inhabitants as per population census of 2014. The division is principally agricultural with approximately 80.000 farmers as per statistics from the divisional delegation of agriculture. Due to lack of funds, the College of Technology could afford one machine under the financial assistance of the mayor of Bangem. The council proceeded with the selection of farmers based on the variety of farm produce and the capability of paying the maintenance fee for the upkeep of the machine. The process resulted to a selection of twenty (20) farmers who represented approximately 0.25% of the entire farming population of the division.

Pre-implementation Statistics

Statistics from the divisional delegation of agriculture show that the following agricultural commodities are cultivated in the kupe-manegouba division: cassava, cocoyam, plantains, maize, pepper, irish potatoes, beans, cabbages, tomatoes, palm oil, coffee, cocoa. The total surface area used is 13063 hectares for a total per annum production of 3913982 tons with plantains constituting the bulk of the production with 3900000 tons. The detailed statistics displaying the postharvest losses for each agricultural commodity is shown in table 2.

Table 2: Postharvest Losses for Agricultural Commodities in Kupe-manegouba Division

S/N	Crops	Surface (ha)	Production (T)	Post-Harvest losses (%)
1	CASSAVA	2651	8400	20
2	COCOYAM	176	521	20
3	PLANTAINS	2878.5	3.900.000	35
4	MAIZE	583.6	1548.3	25
5	PEPPER	41.1	22.3	30
6	IRISH POTATOES	13.5	53.6	40
7	BEANS	52	85.5	20
8	CABBAGES	11.6	42.5	15
9	TOMATOES	28	90	30
10	PALM OIL	46.5	15.5	20
11	COFFEE	5066.1	3110	20
12	COCOA	1515.1	93.7	30

The postharvest losses could be higher if not of traders who exploit farmers by buying their produce at giving away prices of say 200FCFA per bunch of plantains to sell later at 5000FCFA. The situation is worst during the raining season with traders finding it difficult to get to farmers in the remote areas due to the deplorable conditions of the road. During this period the farmers are in dire need of revenue since it is not possible to sell the produce even at giving away prices.

Post-implementation Statistics

Twenty (20) farmers in Muebah village in Nninong-Bangem in the Bangem sub-division were selected for the implementation of the technology. The mayor of Bangem provided funds for the purchase of the machine while the participating farmers were charged a minimal sum of money for the maintenance of the machine. The agricultural commodities processed were plantains, maize, pepper, irish potatoes, tomatoes, cocoa. Table 3 shows the statistics for the processed commodities for the entire division while table 4 shows the processed commodities for the twenty (20) selected farmers.

Table 3: Post-implementation Statistics for the Entire Division

S/N	CROPS	Surface (ha)	Production (T)	New Production (T)	Original Post-Harvest losses(%)	Gain (%)	New Post-Harvest losses(%)
1	PLANTAINS	2878.5	3900000	3984240	35	2.16	32.84
2	MAIZE	583.6	1548.3	1626.5	25	5.05	19.95
3	PEPPER	41.1	22.3	23.1	30	3.79	26.21
4	IRISH POTATOES	13.5	53.6	54.3	40	1.22	38.78
5	TOMATOES	28	90	92.6	30	2.91	27.09
6	COCOA	1515.1	93.7	96.8	30	3.34	26.66

Table 4: Post-implementation Statistics for the 20 Selected Farmers

S/N	CROPS	Production (T)	New Production (T)	Original Post-Harvest losses(%)	Gain (%)	New Post-Harvest losses(%)
1	PLANTAINS	975.00	1160.49	35	16.0	19.0
2	MAIZE	0.39	0.49	25	20.4	4.6
3	PEPPER	0.01	0.01	30	17.5	12.5
4	IRISH POTATOES	0.01	0.02	40	14.6	25.4

5	TOMATOES	0.02	0.03	30	16.8	13.2
6	COCOA	0.02	0.03	30	17.2	12.8

The postharvest losses for these commodities reduced drastically, for example we recorded a postharvest loss for plantains of 19% as compared to 35% initially for the group of selected twenty (20) farmers. However, the total postharvest loss for the entire division did not change significantly as shown in table 3, with that of plantains being 32,84% since most of the farmers and agricultural commodities could not be covered due to lack of funds. In addition, table 3 shows that, there is an average gain in postharvest losses of 3.08% with maize recording the highest gain of 5.05% implying that, the percentage postharvest loss dropped from 25% to 19.95%. From table 3, the average postharvest losses per annum computed as 28.6%. As indicated in section 2, the drone is launched from the divisional headquarters of Bangem in the kupe-manegouba division of the Republic of Cameroon to detect cases of abnormal crop growth due to pest and appropriate time for harvest. The farmers are assisted with a soft loan by NIBABLIFE to purchase pesticides and the money retrieved after sales of the farm produce. Meanwhile, SOWEDA ensures the sensitization and technical assistance of the farmers and the cooperatives. These partnerships contributed in the increase of production.

Projected Postharvest Losses with Broad-based Partnerships

The College of Technology of the University of Buea envisage to establish broad-based partnerships with national and international stakeholders to increase the level of coverage to reduce postharvest losses to less than 5% by 2030 for all the agricultural commodities in the kupe-manegouba division and beyond. To achieve this feat, the College of Technology will seek for additional funding from national and international partners based on the following calculations.

- The capacity of the first version of the drying machine which won the first prize during the national competition in Maroua, Cameroon in 2019 is 275L.
- Of recent, this capacity has been upgraded in our second version of the drying machine to 2750L
- The cost of production of the machine stands at two million francs CFA (2000000FCFA) which is equivalent to $3,636.
- The cost of production of the drone stands at seven hundred thousand francs CFA (700000 FCFA) which is equivalent to $1273
- Based on the drying time of the machines, each machine can dry 19570 tons of agricultural commodity. With a total per annum production of 3913982 tons for the entire kupe-manegouba division, approximately two hundred (200) drying machines and a single drone for information gathering are required.

- Hence, the total amount required to cover the entire division is
  200 machine x 2000000FCFA + 700000FCFA = 400,700,000 FCFA = $728,545

Table 5 shows the projected production for 2030 with the broad-based partnerships to attain the 5% postharvest losses.

Table 5: Projected Postharvest Losses by 2030

S/N	CROPS	Surface (ha)	Production (T)	Post-Harvest losses(%)	New Production	Expected Post-Harvest losses (%)	Gain (%)
1	CASSAVA	2651	8400	20	8668.8	3.20	16.80
2	COCOYAM	176	521	20	536.9947	3.07	16.93
3	PLANTAINS	2878.5	3900000	35	4154231.3	6.52	28.48
4	MAIZE	583.6	1548.3	25	1620.3927	4.66	20.34
5	PEPPER	41.1	22.3	30	23.546013	5.59	24.41
6	IRISH POTATOES	13.5	53.6	40	57.5932	7.45	32.55
7	BEANS	52	85.5	20	88.92855	4.01	15.99
8	CABBAGES	11.6	42.5	15	44.5145	4.74	10.26
9	TOMATOES	28	90	30	95.02875	5.59	24.41
	PALM OIL	46.5	15.5	20	16.1231	4.02	15.98
10	COFFEE	5066.5	3110	20	3258.036	4.76	15.24
11	COCOA	1515.1	93.7	30	98.935488	5.59	24.41
SUMMARY		13063.4	3913982.4	25.416667	4168740.1	4.93	20.48

Conclusions

In this paper, the use of appropriate technologies to curb poverty and hunger in the rural areas of sub-Saharan Africa due to poor postharvest processes by farmers and how the College of Technology of the University of Buea has sought public, public-private, and civil society partnerships to maximize the impact of the technological innovation is proposed. Postharvest processes present a major challenge in rural areas in sub-Saharan Africa because of rapid degradation of farm produce before delivery to urban markets due to poor road infrastructure. The technologies developed is a drone for data gathering and a new multi-crop drying machine. The area of implementation of the technological innovation is the kupe-manegouba division of the Republic of Cameroon due to its enclaved nature with less than 10 kilometres of tarred road. Statistics from the divisional delegation of agriculture show that the following agricultural commodities are cultivated in the kupe-manegouba division: cassava, cocoyam, plantains, maize, pepper, irish potatoes, beans, cabbages, tomatoes, palm oil, coffee, cocoa. The total per annum production is 3913982 tons with plantains constituting the bulk of the production with 3900000 tons. Such a production potential for a division with less than six hundred inhabitants is adequate to ensure zero hunger and no poverty to inhabitants in the division and beyond. Due to poor postharvest practices, the postharvest loss for the agricultural commodities is enormous ranging from 15% for cabbages to 40% for Irish potatoes. The percentage loss for plantains stands at 35% implying that 1365000 tons of plantains are lost annually. This percentage could be higher if not of traders who exploit farmers by buying their produce at giving away prices of 200FCFA per bunch to sell later at 5000FCFA. Such practice will enhance poverty and hunger for the local farmers. With the implementation of the technologies and local partnerships, the postharvest losses were reduced to an average 20% per annum and it is envisaged that, with broad-based partnerships, the postharvest losses could be further reduced to less than 5% by 2030. We recommend an additional funding of $728,545 through partnerships for the innovative technology to eliminate poverty and hunger to its residual level in the kupe-manegouba and beyond. Eliminating poverty (SDG1) and hunger (SDG2) will have a positive ripple effect on other SDGs since rural exodus and crime wave will be greatly reduced and health care will be affordable.

Limitations

This research had limitations, which included limited resources, which prompted us to use a limited scope of the survey and other methods of data collection. We had one multi-crop drying machine and one drone which reduced considerably our capability to attend to many farmers and to process all the varieties of farm commodities in study. Hence, the total postharvest loss for the entire division did not change significantly since most of the farmers and agricultural commodities could not be covered due to lack of funds.

Originality

This document is an original concept of the team members of Industry, Innovation, and Infrastructure SDG 9. The originality is on the technological innovation and the method of data collection in postharvest processes.

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