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A Review of E-Agriculture Applications in Developing Countries for the Youth: Challenges, Opportunities and Open Issues

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ABSTRACT

The need to incorporate ICT in agriculture is gaining popularity in order to meet the consumer demands of agricultural produce. For developing countries, e-agriculture has potential for many applications that improve quality and productivity in the agricultural sector. The youthful generation in developing countries is more receptive to adapting to ICT and its application areas and can be more receptive to the application of e-agriculture. Its potential is mainly driven by increased access to mobile communication and government policies that promote e-governance. However, realizing the potential of e-agriculture is faced with many challenges. The majority of applications to use in e-agriculture are still only in research stages and there is no clear direction on commercializing research outputs. The research is also disjointed and not well coordinated as there are no policies that clearly state which areas to prioritize. Regulation to govern the development and management of e-agriculture applications is also nonexistent.

Keywords: e-agriculture, commercialization, sensors, cloud computing, security, regulation.

1.1 INTRODUCTION

According to Food and Agricultural Organization (FAO), over 60% of Africa's population is below 25 [1]. The majority of these youths are unemployed. The rate at which the population is growing is lower than the rate at which jobs are being created. The agriculture sector has great potential to create employment in sub-Saharan Africa and provide livelihood for most of the unemployed youths. The demand for agricultural produce is ever increasing with the rise in population. However, the number of youths that are engaged in agricultural activities are very few. There is a general tendency by youths to shun away from agriculture. Researchers believe that incorporating technology in agriculture can encourage the youth to participate in order for them to earn a living [2]. Countries such as Kenya have witnessed a growing number of youths participating in agricultural

activities as a result of the introduction of Information and Communication Technology (ICT) [2]. In Zambia, the Second National Agricultural Development Policy (SNAP) vision is aimed at promoting food and nutrition security, increase employment opportunities and income [3]. The policy goes on further to make special mention of implementing agricultural based technologies for the youth and the women as they are considered to be a special category that require to be encouraged to participate in agriculture.

E-agriculture utilizes Information communications Technology (ICT) and Internet to deliver enhanced agricultural services and information provision [4]. E-agriculture involves designing and implementing innovative ICT applications that support different areas of agriculture. The application areas include control, monitoring, prediction and logistics. E-agriculture offers a new dimension to the way agriculture is managed. This paper brings out the challenges, opportunities and open issues that are hindering that path to unprecedented growth of e-agriculture in developing countries especially in Zambia among the youth.

1.2 PROBLEM STATEMENT

E-agriculture is a new term that has been introduced in agriculture. It is set to improve some of the inefficiencies that exist in agriculture. Zambia's National Information and Communication Technology Policy that was implemented in 2006 lists agriculture as one of the areas where ICT should be applied in order to bring about social economic development. The policy sets ICT to play a major role in making agriculture competitive by supporting activities related to planning, implementation, monitoring and delivery of information [5]. The strategies that were set out in the policy included creating an integrated agricultural information system, implementing weather and meteorology early warning systems and developing a database application and other systems that promote the sustainable utilization of agricultural resources.

Despite the policy being in place, many of the strategies that were outlined have not yet been implemented. Apart from the lack of implementation of these strategies, other issues have also emerged. The issues include youth and women being viewed as the ones to drive the future of agriculture [3]. This study seeks to answer the following questions in relation to the youth.

- a) What opportunities can e-agriculture bring to developing countries?
- b) What are the challenges of implementing e-agriculture in developing countries? and,
- c) What open issues affect e-agriculture in developing countries?

In order to answer the questions a systematic review of existing literature was conducted for developing countries. Since the focus was on Zambia the majority of the literature focuses on the Zambian context. The period selected for review is between 2006 and 2018. The period was chosen because 2006 marks the beginning of the Zambia's National Information and Communication Technology Policy that included integration of ICT in agriculture.

1.3 E-AGRICULTURE APPLICATIONS

1.3.1 Other Countries

A) Nano Ganeshi India

Nano Ganesh has been implemented in India since 2014 and has more than twenty thousand small scale farmers [6]. The Nano Ganesh unit has an actuator attached to the irrigation pump for switching the pump on and off using GSM commands. The unit has a water sensor which enables farmers to check for water availability near the pump and the unit also enables farmers to check for availability electricity at the pump. This system allows farmers to control the irrigation pump from anywhere as long as they are connected to the GSM network.

B) Kilimo Salama: Kenya and Rwanda

Kenya and Rwanda use a system called Kilimo Salama (Safe Farming) weather index insurance programme that has been in existence since 2009 for 64,000 smallholder farmers [7]. The programme offers lower insurance premium to smallholder farmers. The programme utilizes solar powered weather stations that collect weather data every 15 minutes and uploads the information for storage and analysis later. The stored measurements are compared to historical data in order to calculate the insurance pay out at the end of a growing season. The system uses low cost SMS for marketing and dissemination of information as a result of partnership

between Kilimo Salama and Safaricom. The partnership does not only end on providing low- cost SMS services but extends to the way pay outs are handled. M-PESA a mobile based financial service is used to make the pay outs.

C) Wireless Sensor Networks: Kenya and Indonesia

In Kenya and Indonesia Wireless Sensor Networks that use solar power are installed in some tea plantations [8]. The Wireless Sensor Networks monitor moisture, pH, carbon, nitrogen, calcium, potassium and magnesium levels in the tea plantations soil. The measures are taken every 15 seconds and sent wirelessly. The aim of this system is to improve the quality of tea.

D) Croplift: Uganda

Croplift is another service that is being piloted in Uganda [9]. The system is designed to authenticate agriculture inputs using scratch labels and SMS system. The system provides farmers with an opportunity to verify that the inputs they are purchasing are genuine. The SMS system connects to the Ministry of Agriculture to verify whether the scratch label entered belongs to a genuine product. The system has been implemented by the ministry of Agriculture in Uganda to eliminate the problem of counterfeit products in farming inputs. The implementation of e-agriculture in other developing countries shows that ICT can bring benefits to the agricultural sector.

1.3.2 Application Development to E-agriculture in in Zambia

A prototype to reduce theft of input such as fertilizer under Farmer Input Support Programme (FISP) in Zambia has been proposed and tested [10]. The system uses barcodes placed on bags containing the input to identify each bag and record the data in a database in the cloud. Regular updates are made to the database to reflect the changes in inventory levels when input moves from one storage location to another. The input inventory management system arises out of the need to reduce theft of inputs which stands at 56% in warehouses.

A grain inventory management system for the Food Reserve Agency in Zambia using RFID and Cloud storage services was proposed [11]. The proposed system requires placing RFID tags in each bag brought to the storage warehouse. RFID readers positioned on doors of warehouses take note of bags entering and leaving the warehouse. The use of RFID readers is expected to monitor accurately the movement of bags

in and out of the warehouse. The data read by the RFID reader is supposed to be stored in the Cloud and the system can replace the existing paper-based system. The benefits of the system are that it can minimize the theft of grain in warehouses after the harvest period.

Another system that has been proposed extends on the work of [11] to include the aspect of tracking grain that is in transit [12]. The proposed system uses GPS technology to track the vehicles that carry grain from one storage warehouse to another. The aim of the system is to improve on the security of the grain by monitoring that the grain that leaves the warehouse is the same grain that arrives at the destination warehouse. Furthermore, it tracks that the vehicles carrying the grain using designated routes.

Another system proposed is based on using Android and wireless sensor networks to monitor environmental conditions in storage warehouses for the Food Reserve Agency Zambia [13]. The environmental conditions that are monitored include temperature, humidity, water and motion. Temperature and humidity important to maintain and prevent spoilage of produce kept in warehouses. The parameters are continuously monitored to ensure they are within the set limits. Flooding in warehouses can also cause spoilage of food and the system monitors that using the water level sensors. Finally, the issue of theft cannot be overlooked and the system uses motion detection to detect the presence of intruders within the warehouse.

A model based on Zigbee, GSM, cloud and mobile application has been proposed to monitor temperature, humidity and presence of intruders in a poultry house [14]. The proposed model uses open source boards, zigbee protocol, and GSM shield to collect data from the poultry house and send it to a web application in the Cloud. Extreme values of temperature and humidity are relayed to the farmer using SMS and through the web application. Farmers are notified of the presence of intruders in the poultry house using a phone call and SMS received via GSM network. The system is expected to provide early warning to farmers for extreme environmental conditions and presence of intruders in the Poultry house.

1.4. CHALLENGES OF E-AGRICULTURE APPLICATIONS IN DEVELOPING COUNTRIES

A. Commercialisation of Research Outputs

Zambia's National Information and Communication Technology Policy of 2006 requires Higher Education institutions to be leaders in research and publish results of their experiments [5].

Furthermore, the policy requires Higher education Institutions to be leaders in testing new ICT technologies and make recommendations to the government, private sector and society. A number of publications have been made by Higher Education institutions in different research areas including e-agriculture. However, many of these research publications have only resulted in academic promotion and giving qualifications to students [15]. There is no deliberate policy or an existing framework that can be used to commercialize the output of the research. Having guidance on how to commercialize research outputs can go a long way in solving problems in society that are location specific. It is also possible to start business ventures from research outputs especially among the youth. The lack of commercialization affects different subject areas not just e-agriculture applications.

B. Lack of well-Coordinated Research Platform

Looking at the number of ICT applications that are being developed in the agriculture sector. There seems to be no proper guide as to what research direction the country is supposed to take. The application are usually developed on an ad hoc basis without reference to a guide that is supposed to govern the research direction of applications to be developed. The current research applications in e-agriculture seem to focus on responding to ad-hoc problems that arise within agriculture. Existing policies only direct research institutions to be leaders but, do not provide a guidance on how to coordinate research among different higher learning institutions [5] [3]. A good number of youths pass through these research institutions where they can acquire knowledge to be innovators and implementers of e-agriculture.

C. Challenges in Accessing Information

The move towards implementing and offering government services using ICT is a welcome one. In terms of e-agriculture, the emphasis on providing local content cannot be overlooked. The content provided to the farmers, sometimes must be translated in local languages to improve understanding by the farmers [9]. Offering information to farmers using ICT has not been an easy task to achieve. Some of the reference materials that farmers need is still written in a language that the farmers cannot understand. Furthermore, there are challenges in terms of providing information to farmers in a timely manner. An example that can be given is that of the ministry of Fisheries and livestock. The ministry was set up in 2015 after

the Ministry of Agriculture was split but at the time of writing the ministry does not have a website. This in itself brings a challenge to farmers that want to access up-to-date information from the ministry on their own without the need to travel to an agriculture office.

D. Financial Constraints

E-agriculture requires some form of investment. The investment may be required to purchase equipment and maintain it. However, many developing countries do not provide financial products that can be used by both innovators and implementers to invest in agriculture technology [1]. The lack of financial products designed specifically for investing in agriculture slow down the implementation of ideas and the subsequent use of innovation that come from such ideas. The existing financial products are more general and usually require collateral when borrowing. This tends to discourage the youth from utilizing such products because they may not meet the requirements expected.

E. Fragmented ICT Infrastructure, Poor Services

The existing ICT infrastructure in Zambia is highly fragmented [17]. Some of the infrastructure is owned by the private sector while others are owned by government agencies. The fragmentation makes it difficult to develop a holistic approach that can be applied in e-agriculture. In addition, the services provided in the telecommunication sector are poor. A case in point is where Zambia Information and Communications Technology Authority (ZICTA), the regulator in Zambia fined three service providers namely Airtel, MTN and Zamtel for poor quality services in 2018 [18]. The fines were for poor services related to SMS, Call setup and HTTP access. Most of the equipment that is required to improve the ICT infrastructure is usually imported from outside the country. This in itself is a challenge to the innovators as they have to import nearly all the gadgets that are required for them to develop their applications. Even basic devices such as sensors and microcontrollers are never sold in retail electronic shops in the country for easy access.

F. Lack of Skilled ICT Personnel

The National Information and Communication Technology Policy also puts an emphasis on the training of manpower in public and private sector in ICT [5]. There is a general shortage of ICT skills in both public and private sector [17]. This makes it difficult to implement some of the strategies that are required to achieve integration of ICT in agriculture. Great strides have been made in trying to train personnel with the introduction of different ICT programmes at public universities and colleges. Other private institutions have also

been established to train the required human resource. Despite these efforts there is still a shortage of ICT skills.

1.5 OPPORTUNITIES OF E-AGRICULTURE

A. Increased Network Coverage

The coverage area for mobile cellular networks is high at 92% in Zambia and 64% of households having access to a mobile phone [22] [23]. Such high coverage and increased subscription provide opportunities for implementing local e-agriculture applications. In other countries, SMS applications prove to be prominent in agriculture and can easily be accessed on almost any mobile device. SMS does not require internet connectivity in order for it to work hence making it popular even in rural communities. SMS applications in other developing countries are successful at providing marketing information, weather forecast, ordering of inputs, banking services to small scale farmers.

The second national agriculture policy has placed an emphasis at promoting SMS based extension services [3]. This provides opportunities for innovative solutions that can be used to provide extension services using SMS. In addition, SMS could prove useful at providing information from early warning systems to farmers. It has been demonstrated in some of the research applications that SMS can also be used to provide real time information to the farmer regarding the status of their livestock [14].

Running voice-based messaging systems alongside SMS could help to bridge the barrier that is there for farmers that cannot read. Voice based applications can be provided in local languages making the information dissemination easy to understand. Having applications that are innovative in such areas can promote e-agriculture among the small-scale farmers. The small-scale farmers can also include the youth who are much more conversant with the use of mobile phone technology. Accessing such information services will just seem as normal as using traditional text messaging that the youths are already used to.

B. High Demand of Agricultural Produce

The rate at which the population is growing is high and the demand for agricultural produce also increases proportionally [1]. There is great potential in providing and selling agricultural produce to the ever-growing population. There is a need to find ways of improving agriculture production and quality of produce that is delivered to the market. Other areas that may require

improvement include logistics for managing the distribution of both agricultural produce as well as agricultural inputs. This provides opportunities for the youth to come up with innovative solutions that can improve the quality of produce or increase the production capacity. Experiments have already started in this area that can monitor the environment to ensure the parameters required in agriculture are within the set limits to achieve high production. Other systems under experimentation are aimed at providing security of goods that are in transit. This is just a start of many applications that target meeting demands of consumers.

C. SMART Zambia Master Plan

The move towards providing e-governance systems has resulted in the smart Zambia master plan. The first phase of this plan was to establish a data center that could be used by government as well as the private sector to provide storage and other Cloud services [19]. The second phase is to provide optic fiber connectivity across the country. Other developments related to infrastructure included installation of cell Towers. This development of infrastructure provides opportunities of implementing e-agriculture since the platforms for storage and now available. Unique applications can be developed in e-agriculture that utilize the processing capability of the data center and high data rates offered by optic fiber [17].

D. Productive Capabilities and Decision-Making

Applications that collect information have the ability to transform the way decisions are made. Information can be collected about weather conditions, diseases, pests, market performance and other useful information in agriculture. The data center could prove to be useful tool for analyzing data required for decision making. Incorporating SQL databases and data mining can help make predictions about the future such as weather forecast in relation to climate change [20]. The wider network coverage can be used to disseminate such information to farmers using various ICT platforms. With the right training, the youth can be encouraged to utilise such information and make informed decisions concerning their agricultural businesses. Systems that have predictive capability can also be useful by policy makers in guiding long term decision-making concerning the agriculture sector.

E. Lower Coast of Production

Incorporating ICT in agriculture has the potential to lower the cost of production. For example, the use of early warning systems about weather conditions or pests can help farmers in the reducing the impact of such problems. The cost of technology such as sensors has reduced and therefore cheaper solutions that require use of sensors can be implemented. It is possible for small scale farmers to

have access to affordable ICT technology to support their agricultural activities. In turn, the information such systems provide to the farmer enables them to minimize losses that can result if such systems were not in place.

F. Social Media Platforms

In most developing countries many youths are on social media platforms and own smartphones. Social media can be a good platform to disseminate agriculture information to youths that are engaged in farming. Countries such as Kenya utilise social media to share information such as marketing and farming trends [2]. There are some groups on social media such as Facebook in Zambia where young farmers actually market their products. The ministry of Agriculture and Cooperatives in Zambia has a presence on Facebook to disseminate information to farmers that have access to such platforms. Social media has great potential to improve communication for young farmer 's community. Social Media platform cannot only be restricted to text information but, can include videos to provide training. With the coming of networks that support 3 G and 4 G technology, social media can go a long way in providing training information to farmers

G. Weather Based Insurance

The second national agriculture policy has made special mention of implementing weather-based insurance schemes for small scale for the farmers. This idea has worked in Kenya and Uganda under the project called Kilimo Salama [7] [3]. This provides an opportunity for insurance companies, mobile service providers and innovators of ICT technology for agriculture to come up with such products to meet the demands of farmers. Lessons can be learnt from other countries that have implemented and succeeded. This opportunity is for both the young innovators, farmers and farmers in rural communities.

1.6 OPEN ISSUES

A. Ownership of Collected Data

The ownership of data that can be collected from the farming community is not clearly defined. Should this data be owned by private sector or should ownership be in the hands the public sector. For example, personal information of farmers can be obtained in order to know where they are located, what type of farming they are engaged in and other details. The next question to ask is who owns this data that has been collected and for what purpose is it going to be used for. These are issues that

need to be outlined in some form of policy to guarantee that individual's privacy is protected as well as the information about the farming activities is also protected.

B. Regulation in E-Agriculture

There are no specific policies that regulate e-agriculture applications within Zambia. As much as more investment may be sought to invest in the agriculture sector, it is important to put in place a regulatory framework that governs how players in the sector are supposed to conduct the operations. The existing framework is general and not specific to the agriculture sector which makes it difficult to deal with issues that may arise in terms of managing the digital content that can be generated [17].

C. Security of Data

In the 7th National Development Plan and the Second National Agriculture policy, the government of Zambia has planned that technological advancements in agriculture should be led by the private sector [3] [17]. But there are still questions that need to be answered such as, how is security of any electronic data generated going to be guaranteed? The setting up of the data center is a good move in terms of providing storage facilities to both public and private sector. However, it is a well-known fact that security in the Cloud is still an issue that has not been resolved [21] For example, if applications are developed that require to control actuators within the farming set up the chances of that system being controlled by unknown people are always there. Due to lack of concrete security measures implemented in cloud storage facilities the issue of widespread use of such technology in managing critical applications in agriculture will still remain to be a challenge.

1.7 CONCLUSION

The majority of the farmers in Zambia are in the small-scale category. The focus of the second national agriculture policy is to encourage women and youths to participate in agriculture by promoting agriculture technology. Introducing e-agriculture practices has the potential to encourage more youths to participate in agriculture and reduce levels of unemployment. Opportunities in innovation can range from SMS applications, mobile payment systems, social medium information sharing.

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