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AN mAGRICULTURE FRAMEWORK FOR AGRICULTURE INFORMATION SERVICES DELIVERY

***[1]Okediran O. O., [1]Ganiyu R. A. and [2]Badmus T. A.**
[1]Department of Computer Science and Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
[2]Department of Computer Engineering, Federal University, Oye-Ekiti
***ookediran@lautech.edu.ng (Corresponding Author)**

ABSTRACT

Agriculture is an information intensive industry that is spatial in nature. For farmers to thrive, they must be generalists who are well versed in the latest farming technologies. Thus, farmers need to be well informed on the best agricultural practices, prime farming operation techniques, optimum methods of management, prevailing post harvest operations and transactions and so on. However, Nigerian and African agriculture in general is disadvantaged owing to factors that include: poor access to agriculture-related information, deficits in physical infrastructure, high transactional costs, digital divides, low literacy level, problems with availability of agricultural inputs to mention but a few. In this paper, we present an mAgriculture framework for agricultural information services delivery using the communication channels available on a feature phone. Features phones are easy to use and are increasingly able to bypass the barriers of illiteracy and affordability, and they provide access to a wide range of very useful services, such as transferring money, checking market prices, gathering weather information, obtaining personal agricultural extension and other professional advice. The three basic communication channels of feature phones employed by the developed framework are: voice, short message service (SMS) and Unstructured Supplementary Service Data (USSD) with the intent of providing a platform where farmers' need of agriculture information could be met.

Keywords—Framework, Mobile Phone, Information and Communications Technology, Interactive Voice Response, Short Message Service, Unstructured Supplementary Service Data

1 INTRODUCTION

Agriculture is the largest economic sector in most African countries and remains the best opportunity for economic growth and poverty alleviation on the continent, contributing about 17% to the Gross Domestic Product (GDP) and 40% to exports, besides creating employment (Munya, 2007). GDP growth generated by agriculture is up to four times more effective in reducing poverty than growth generated by other sectors (Quantus, 2011). In sub-Saharan Africa, agriculture still accounts for one-third of the GDP and three-quarters of employment (World Bank, 2008). It remains a very important economic sector in Africa not just because its contribution to GDP and employment, but also because of the multiplier effect it has on the economy, which ranges between 1.5 to 2.7% (UNECA, 2009). In Nigeria, agriculture contributed 24.44% to nominal GDP as of the third quarter of 2017, (NBS, 2017). Despite the key role agriculture plays in the economy of Nigeria and many African countries, it faces major challenges that have hindered the exploitation of its full potential to the economic contribution. Also, Africa's agriculture sector has been in decline over the past 40 years (Quantus, 2011). Nigerian agriculture like other sub-Saharan Africa's agriculture is largely traditional and practiced by smallholders and pastoralists. It is predominantly rain-fed and low-yielding, with farmers being trapped in a cycle of poverty and food insecurity for decades. Most farmer in these countries are smallholders (Lotter, 2007), and the challenges encountered by these farmers is multidimensional including: sub-divisions and small farm sizes, leading to diseconomies of scale and low productivity; inadequate knowledge and skills in modern farming techniques (poor agricultural practices) and optimum methods of management; inefficiencies in information delivery; information on best practices; storage difficulties and inadequate farmer experience with the marketing of produce; poor linkages between farmers, processors, markets, researchers and extension workers (Tiamiyu, Bankole and Agbonlahor,2012; Munyua and Adera, 2009; Gichamba and Lukandu, 2012). It was also noted by (Munyua and Adera, 2009) that farmers in developing countries often lack adequate information on inputs, markets, credit, improved technologies, commercial farming and other aspects of rural development. These have resulted in large imports into many African countries, low food security levels and limited expendable income to rural households. Although large amounts of development funds have been donated by a number of leading development agencies with the objective to stimulate agricultural production and reduce poverty, most of those attempts have unfortunately failed (Deloitte, 2012).

The increase in affordability, accessibility and adaptability of information and communications technologies (ICT) has created a breeding ground for development innovations, which target key areas of economic and social impact such as agriculture, education, health and finance. Small devices (such as multifunctional mobile phones and nanotechnology for food safety), infrastructure (such as mobile telecommunications networks and cloud computing facilities), and especially applications (for example, those that transfer money or track an item moving through a global supply chain) have proliferated (Mcnamara, 2011; Deloitte, 2012). In Nigeria, the proliferation of mobile phones has

resulted in their use even within impoverished rural homesteads relying on agriculture. Mobile phones are easy to use, are increasingly able to bypass the barriers of illiteracy and affordability, and provide access to a wide range of very useful services, such as transferring money, checking market prices, gathering weather information, obtaining personal agricultural extension and other professional advice (ICT Update, 2013). Many of the information needs that could improve smallholder livelihoods can be fulfilled with the effective and easy use of ICT. ICT is a key resource for economic development and growth as it can bridge the critical knowledge gap between stakeholders. However, though ICTs are used widely in large-scale farms and the commercial sector, relatively little attention has been paid to deploying ICTs for small-scale farmers and the associated upstream and downstream actors. ICTs could help small-scale farmers and other associated communities in Africa address some of the issues and challenges they face and enhance communication and delivery of critical knowledge, information and services.

This paper focused on the role of ICT in providing timely information, increasing choices, reducing transaction costs, and contributing to improving the efficiency of decision making of smallholder farmers in crop farming. In crop farming, farmers make critical decisions throughout the year. These decisions include those based on choice of inputs (crop varieties and seeds, water, power, fertilizers and pesticides) and market transactions related to them, farm operations (tillage, sowing, water management, fertilizer management, pest management, harvest), post-harvest operations and transactions (including storage, transport, marketing and processing) and others. Typically, farmers rely on accumulated experience and the support of local organizations (for instance, input suppliers, rural credit agencies, extension services, NGOs) for information related to both farm and non-farm decisions. They also receive information from radio and television broadcasts by experts and professionals from more distant sources. Together, these form the local knowledge system accessible to a small farmer for making decisions. Often, this system is inadequate and many decisions are made with limited information. The decisions are also subject to high transaction costs and time delays. This paper presents a mAgriculture framework for agriculture information service delivery that can provide a means to overcome existing information asymmetry in the Nigerian agriculture. The rest of the paper is organized into the following: Section two presents review of relevant literatures to this research; Section three details the research methodologies employed in the development of the proposed mAgriculture framework; Section four present the results and Sections five summarized and concludes the paper.

2. LITERATURE REVIEW

2.1 ICT innovations in agriculture

ICT4 for Development (ICT4D) involves the usage of ICT as a tool to enhance development, mostly in developing economies. This has increasingly become a vehicle through which critical services in developing countries are provided. ICT4D entails using ICT as a platform of service provision in sectors such as agriculture, health, education and finance in the developing world. Additionally, Mobile for Development (M4D) has emanated from ICT4D, with a keen focus on provision of mobile technology solutions in the aforementioned sectors. Specifically for agriculture, ICT innovations entail the provision of agriculture related services on devices such as computers, tablets, mobile phones and any other hand-held computing device. Like other sectors in the continent, African agriculture is disadvantaged owing to factors that include: deficits in physical infrastructure, problems with availability of agricultural inputs and poor access to agriculture-related information. Some of the challenges facing agriculture stakeholders in developing countries can be tackled by the use of ICT innovations.

This adoption of ICT in agriculture is of strategic importance to five main stakeholders: businesses, farmers, researchers, government and the general citizen (Deloitte 2012). With the proliferation of affordable technology even among the poor small holder farmers, there is an immense opportunity to use ICT to improve yields, provide useful information and generally empower farmers. Increasing agricultural productivity, profitability and sustainability in the developing world depends on the ability of rural populations to adopt changes and innovations in their use of technologies, management systems, organizational arrangements, institutions and environmental resources (Qiang *et al*., 2012). One of the areas that has potential for great impact on agriculture in developing countries is the use of ICT in the agriculture value chain, both in the crop and livestock sectors. Arguably, hunger and poverty is concentrated in developing countries due to poor capacity to develop, to access and to manage agricultural information and knowledge for agricultural production. The strategic application of ICT to the agricultural industry, the largest economic sector in most African countries, offers the best opportunity for economic growth and poverty alleviation on the continent. Furthermore, food security in the developing world, especially in Africa, need to be more knowledge intensive than resource intensive. This is only achievable by considering and incorporating factors such as policy, legal framework, technology, knowledge, markets, research among others, in addressing food security (Awuor *et al*., 2016). In all these, ICT can act as a catalyst to facilitate their incorporation into agriculture. Millions of farm families and the rural poor need right information and knowledge for their agricultural survival. Such information can be easily availed to them through ICT. The use of modern information and communication tools and technologies such as computers, mobile phones, satellites, applications, information systems and digital platforms that increase agricultural productivity and make available information that is relevant to agricultural research, planning, extension, production,

monitoring, marketing and trade is referred to in this paper as e-agriculture. This paper also identifies mAgriculture as the subset of e-Agriculture where mobile devices, including but not limited to mobile telephones, are involved.

2.2 Mobile phones as vanguards of ICTs in agriculture

Mobile phones are but one form of ICT. Personal computers, laptops, the Internet and broadband, mass media (television, radio, and traditional newspapers), satellite and so on are all used to promote improved rural development. However, mobile phones are in the vanguard of ICTs in agriculture and rural development. They have been the most adopted means of communication both in the developed and developing countries with its penetration more than all other information and communication devices put together (Okediran *et al*., 2013). The penetration rates of mobile phones are outstripping those for internet users, fixed phone lines and broadband subscriptions. This is indicated in Figure 1. As of 2018, the international Telecommunication Union (ITU) estimated that there are over 781 million active mobile cellular telephone subscriptions in Africa, with a penetration rate of 76 per 100 inhabitants. In October 2018, the Nigeria Communication Commission estimated that there more than 164 million active mobile telephone lines in Nigeria. Mobile phone technology has been diffused rapidly in the rural areas of the developing countries in recent years. The rate of proliferation of mobile phone globally in last few years is depicted in Figure 2.

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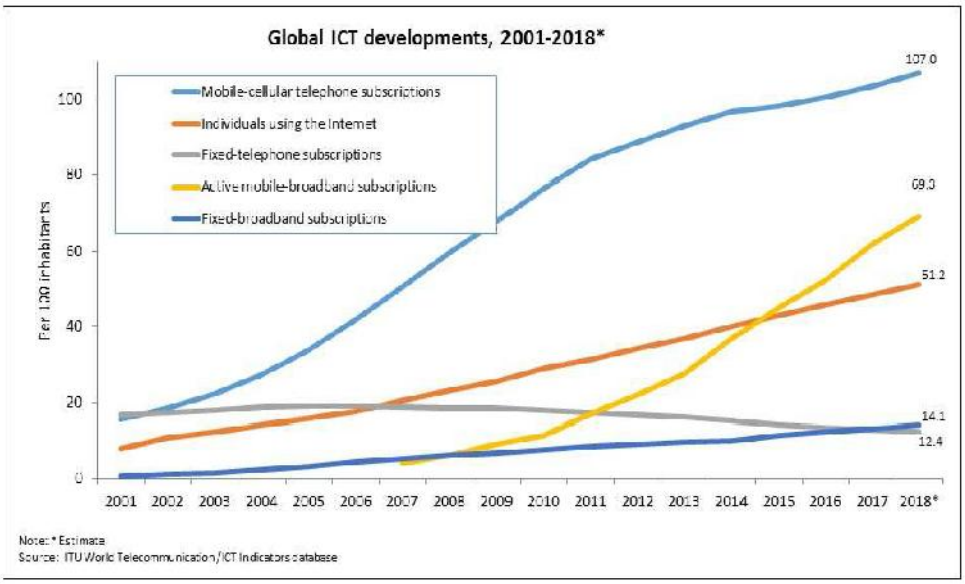

Figure 1: Global ICT Development (ITU, 2019)

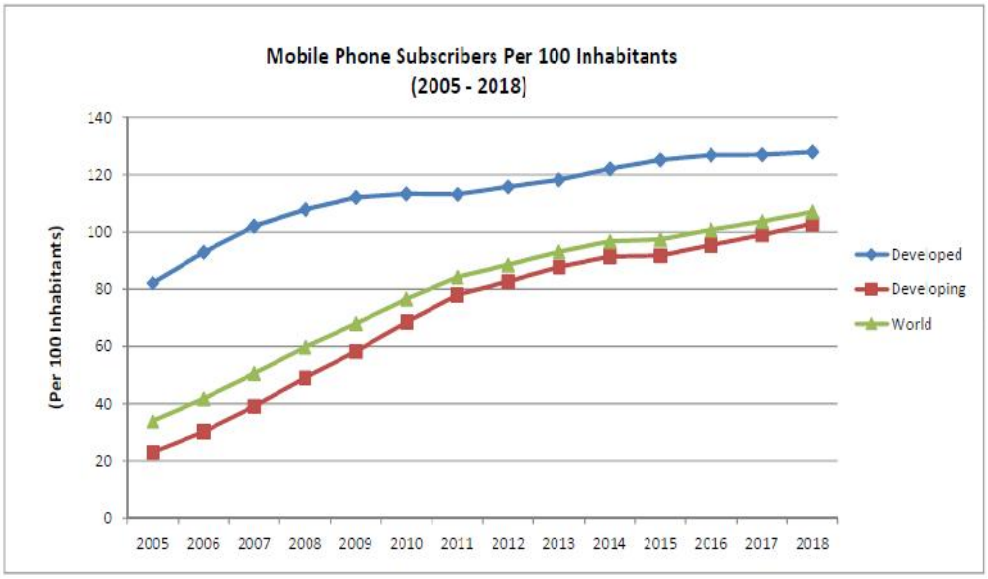

Figure 2: Global Mobile Cellular Subscriptions Growth (ITU, 2019B)

Mobile phones have the advantage over other ICT tools in terms of its appropriateness for the under-developed local conditions. It have been found to help improve the productivity of individuals and organizations within resource-constrained environments as it increases efficiency, effectiveness, and reach (Burrell,2008; Qiang *et al.*, 2011; Hudson, 2006). Other than mobile phones, other ICT tools suffers from the problem of feasibility for the poor in geographically disadvantaged areas because of lack of enabling environments such as infrastructure and capital. For example Internet enhanced technologies are not appropriate in the areas lacking electricity and network infrastructure. On the contrary, mobile phone technology has much less requirement on the infrastructure and hence wider applicability. Many agricultural services may be provided using the major communication and information access functionalities of mobile devices that include installable mobile applications, Voice/ Interactive Voice Response (IVR), SMS, USSD and internet. Other device features that enable a wide array of possibilities in ICT innovations for agriculture include the ability of devices to capture photos and videos, communicate via Near-field Communication (NFC) and Radio-frequency Identification (RFID), as well as Global Positioning System (GPS) functionalities. Most of these innovations are made to work on feature phones, smart phones, and Internet of Things (IoT) devices, mostly depending on the target users, the available ICT infrastructure and the service being provided.

2.3 Roles of mobile communication technology in agriculture

The role of mobile communication technology alone has the potential to transform the rural agricultural landscape in manners that will enhance productivity, data sharing and market access. There are a number of benefits that need mentioning and these include (Donovan, 2011; Deloitte, 2012; Qiang *et al.*, 2012):

i. *Access:* Mobile wireless networks are expanding as technical and financial innovations widen coverage to more areas.
ii. *Affordability:* Prepaid connectivity and inexpensive devices, often available second hand, make mobile phones far cheaper than alternatives.
iii. *Appliances:* Mobile phones are constantly increasing in sophistication and ease of use. Innovations arrive through traditional trickle-down effects from expensive models but have also been directed at the less expensive phones.
iv. *Applications:* Applications and services using mobile phones range from simple text messaging services to increasingly advanced software applications that provide both livelihood improvements and real-time public services. In the agricultural sector these include price information, market links, extension and support and distribution, logistics and traceability.

2.4 mAgriculture applications in developing countries

A substantial number of mAgriculture interventions deployed globally have been done in developing countries where the mobile phone is the primary computing device (Adkins, 2013). In these parts of the world, most mobile phone owners possess a feature phone, although the trend is quickly changing with the introduction of low price smart phones. mAgriculture services are critical in developing countries, as farmers lack access to relevant, actionable and timely agriculture information needed to inform better farming practise and facilitate great productivity (GSMA, 2015). Most mAgriculture applications focus on improving agriculture supply chain integration and have a wide range of functions such as providing market information, increasing access to extension services, the provision of information related to produce market, climate and disease, good agricultural practices, extension services, linkage between farmers, suppliers and buyers (facilitating market links), accounting and traceability, credit, insurance and payment methods (Qiang *et al.*, 2012). The rapid uptake and popularity of mobile phone applications in agriculture by rural farmers have led to the development of unique and innovative approaches to using these applications in solving some salient issues faced by farmers. Several studies have revealed some innovative examples; it has been reported that farmers use mobile phones to coordinate access to agricultural inputs (Martin and Abbott, 2011; Ansari and Pandey, 2013; Syngenta Foundation, 2011; Das, Basu and Goswami, 2012); accessing market information (Odhiambo, 2014; Das, Basu, and Goswami, 2012; Martin and Abbott, 2011); for financial transactions (Qiang, *et al*.,, 2011; Martin and Abbott, 2011; Kirui, Okello, and Nyikal, 2010); and to seek agriculture emergency assistance and expert advice (Qiang *et al.*, 2011; Martin and Abbott, 2011; Churi *et al.*, 2012).

3. RESEARCH METHODOLOGY

The research methods employed are of two phases:

3.1 Needs assessment and analysis

The development of any mAgriculture framework requires the understanding of the current sources of information or services that are utilized by the population being targeted by the mAgriculture intervention. Other factors of importance to consider would be their literacy levels, language proficiency, technical capabilities and the technologies available to them. Three farming communities in Ogbomoso environs were used in this research as case studies to analyse the effects of the adoption of mobile phone on their livelihood. Two out of the sources of data collection techniques proposed by (Yin, 1984) for case study research (direct observation and field interviews) were employed to collect information on mobile phone ownership, device capabilities, services and usage, literacy level and availability of telecommunications infrastructures. A total of 90 smallholder farmers who engage in crop farming were interviewed via a questionnaire consisting of 15 questions. The questionnaires were filled for

respondents by the researchers because of the literacy level of some of the respondents. Questions regarding the perceived relative advantages that led to mobile phone adoption were specifically asked during interviews. Perceived relative advantages included both the maintenance of kinship networks and agricultural purposes, including the abilities to access financial information, and to efficiently coordinate meetings and consult with agriculture extension agents or farm group members.

3.2 Framework design

The mAgriculture framework deployed agriculture information services delivery mechanisms using the communication channels available on a feature phone, which are voice, SMS and USSD. Of utmost importance in the design were the considerations for:

i. *Defining the needs of the target users:* The framework catered for the existing information asymmetry of the target users. The design goal of the framework is to provide a platform where agricultural related information can be easily accessible and available for smallholder farmers in crop farming.

ii. *The availability and appropriateness of the technology to be employed:* The framework utilized feature phones which are the most readily available technology at the disposal of the users. Also, availability of telecommunication infrastructures in the farming communities of the target users was considered.

iii. *The literacy levels of the target users:* The mode of content delivery of the framework was based on the literacy level of the target users. The communication channels deployed for usage by the target users possesses high ease of usage and low technical know-how requirements.

iv. *The willingness of the target users to pay for service(s)*: The cost of accessing the services to be provided by the framework was prioritized in the design process of the framework. Voice (IVR), SMS and USSD were employed as they are relatively affordable.

4. RESULTS AND DISCUSSION

The data analysis of the collated information from the questionnaires is presented in Table 1. Overall, findings suggest that mobile phones are being adopted for agricultural purposes, such as coordinating access to agricultural inputs, - accessing market information, monitoring financial transactions, gaining agriculture advice and saving valuable time and money through increased consultation and coordination.

Table 1: Descriptive Analysis of Respondents

	CATEGORY	FREQUENCY	PERCENTAGE
Gender	Male	74	82.22%
	Female	16	17.78%
Level of Education	None	6	6.67%
	Primary	57	63.33%
	Secondary	25	27.78%
	Tertiary	2	2.22%
Possession of Mobile Phones	Yes	79	87.78%
	No	11	12.22%
Type of Mobile Phone	Feature Phone	75	94.94%
	Smartphone	4	5.06%
Purpose of Mobile Phone Adoption	Kinship maintenance only	3	3.80%
	Kinship maintenance & Agricultural-base purposes	76	96.20%
	Agricultural-base purposes only	-	-
Agricultural Uses of Mobile phones	Coordinating access to agricultural inputs	67	84.81%
	Consulting with expert advice	36	45.57%
	Accessing market information	58	73.42%
	Monitoring financial transactions	23	29.11%
	Agriculture emergency	42	53.1%

Figure 3 depicts the developed mAgriculture framework for agriculture information service delivery.

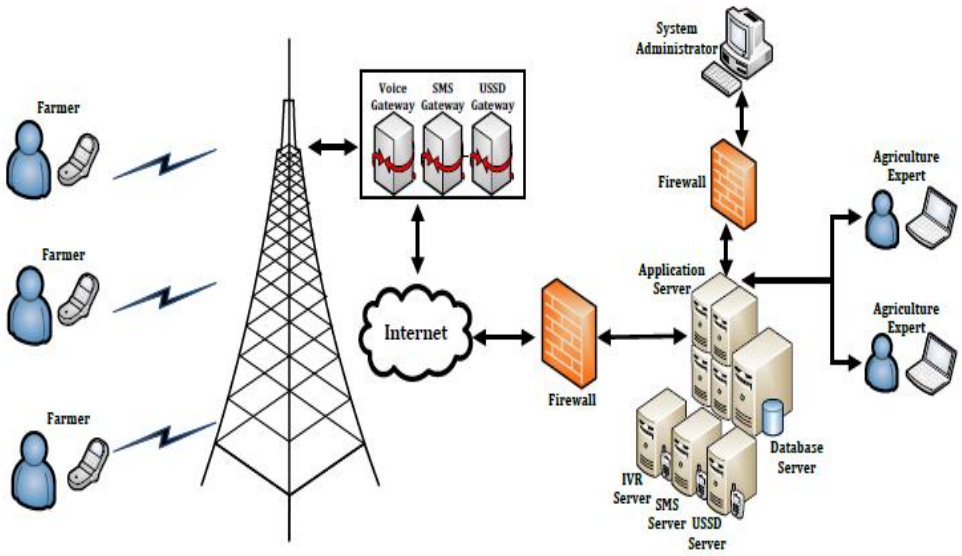

Figure 3: The Developed mAgriculture Framework for Agriculture Information Services Delivery

The framework consists of components which were determined by the need of farmers (that is access to agriculture- related information), technology available to them and the technological infrastructure exposed to them. There are three communication channels for the target users to access the services available on the framework. They are IVR, SMS and USSD. The communication will be facilitated by existing mobile telecommunication infrastructures in the communities of the target users. The application servers contains application running at the back-end to integrate IVR, SMS and USSD from the farmers 'end and web from the agriculture experts' end. The mode of operation of the three communication channels is as follows:

i. *IVR*: The IVR component of the framework can provide can access to agriculture-related information on crop farming from anywhere at any time and in a selected language simply by dialing a specified number and following an on-line instruction when a connection has been established. The IVR component of the framework uses pre-recorded /computer generated voice responses in the database or route the call to the most appropriate agriculture expert to provide information in response to an input from the farmer. The input may be given by means of Dual Tone Multi-Frequency (DTMF) signal, which is generated when the farmer presses a key of his/her mobile phone, and the sequence of messages to be played is determined dynamically according to an internal menu structure (maintained within the IVR application program in that resides on the application server) and the farmer's input.

ii. *SMS:* The SMS component of the framework provides premium SMS services. These services are micro-payment services by SMS. The premium SMS allow users to buy or subscribe to various services or digital content via a short code from 3 to 5 digits. Farmers can request for agriculture-related information via SMS through the framework. A farmer accessing this service on the framework would be required to send a keyword to an SMS premium number and in return the application server (content provider) delivers the requested content or service.

iii. *USSD*: The USSD component of the framework provides instant messaging services. It requires generation of query from the mobile phone of the farmer. Once this request is sent, the USSD gateway forwards it to the USSD application on the application server. The application then responds to the request, and the process is repeated in reverse: the response goes back to the USSD gateway, which displays the content of that response on the farmer's mobile phone. The USSD component of the offers more responsive information services than the SMS component.

The *web* component of the framework integrates the three communication channels available at the client' end of the framework, that is, IVR, SMS and USSD. It is the platform through by which the agriculture experts review and respond to requests posed by the farmers through the aforementioned communication media. It also provides a means by which information can be broadcasted to farmers. Figures 4-6 depict the various use case diagrams showing the interaction between the farmers, the system administrator and the agriculture expert with the framework respectively. The use case diagram is a representation of a user's interaction with the framework that shows the relationship between the user and the different use cases in which the user is involved.

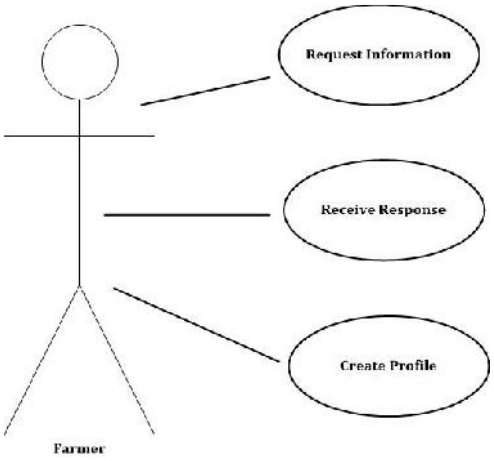

Figure 4: Use Case Diagram of the Farmer

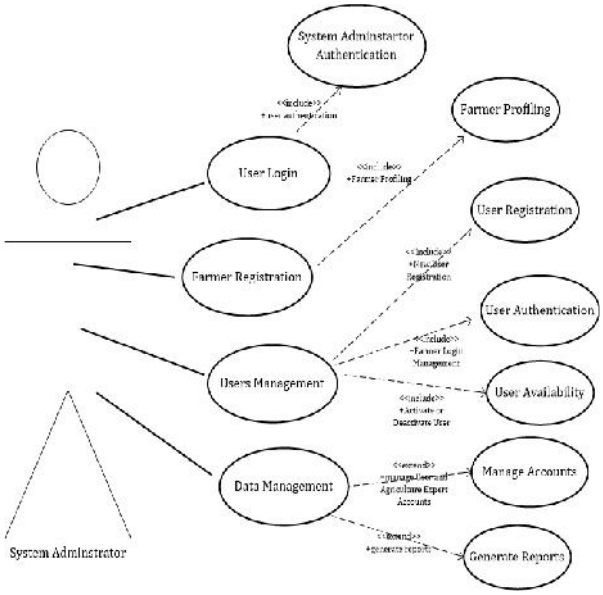

Figure 5: Use Case Diagram of the System Administrator

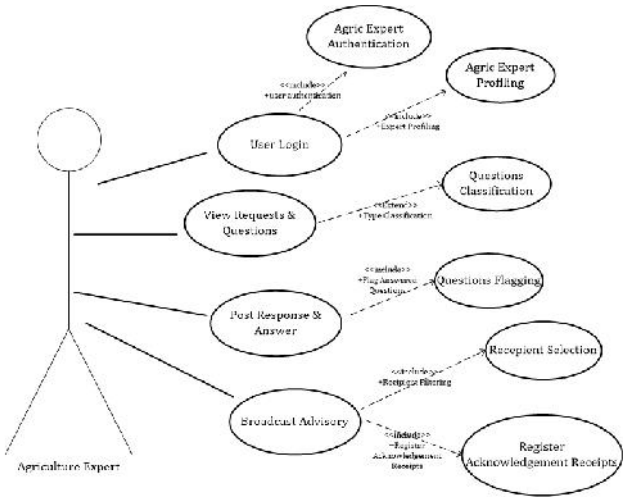

Figure 6: Use Case Diagram of the Agriculture Expert

5. CONCLUSION

Agricultural information is a key component in improving smallholder agricultural production and linking increased production to remunerative markets, thus leading to improved rural livelihoods, food security and national economies. Thus, improvement of agricultural productivity can be realised when farmers are linked to essential agriculture-related information. However, one major problem in many rural areas is that farmers and small entrepreneurs generally have difficulty in accessing such information, because of the highly localized nature of agriculture which means that information pertaining to agriculture must be tailored specifically to distinct conditions. Furthermore, agriculture in developing countries such as Nigeria is plagued by poor access to agriculture-related information, deficits in physical infrastructure, digital divides, low literacy level and so on. The proliferation of mobile phones in developing countries has resulted in their use even within impoverished rural homesteads relying on agriculture. Mobile phones are easy to use, are increasingly able to bypass the barriers of illiteracy and affordability, and provide access to a wide range of very useful information services. This paper has detailed the development of an mAgriculture framework that employed the three basic communication channels available on a feature phone for accessing agriculture-related information that could enhance agriculture productivity, improved rural livelihoods, food security and national economies.

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