AN E-AGRICULTURE FRAMEWORK FOR INCLUSIVE AGRICULTURAL VALUE CHAINS IN NIGERIA

Oladotun Olusola Okediran

Department of Computer Science & Engineering,
Ladoke Akintola University of Technology, Ogbomoso, Nigeria

Corresponding Author: Oladotun Olusola Okediran, E-mail oookediran@lautech.edu.ng

ABSTRACT: Agriculture is an information intensive sector. Therefore, there is a continuous need for farmers to have access to the right information, at the right time, in the right format and through the right medium, which in turn can improve inclusive development of the agricultural value chains. In Nigeria and sub-Saharan Africa in general, one of the major attendant problems facing farmers is poor access to information on markets, market prices and logistics to enhance productivity and profits. However, providing these information can be challenging, because of the highly localized nature of agriculture, it means that information must be tailored specifically to distinct conditions. These contextual information needs can be fulfilled by the effective use of Information and communication technologies (ICTs) in agriculture often referred to as e-Agriculture. The delivery of agricultural information and knowledge services using modern information and communication tools and technologies for agricultural marketing, products pricing, logistics, trade and financial inclusion that increase agricultural productivity, efficiency and sustainability falls under the definition of e-Agriculture. This paper presents an e-Agriculture framework that offers support services to smallholder farmers by providing a platform for accessing information on markets, market prices, logistics and financial services with the intent to enhance inclusive development of the agricultural value chain of the country.
KEYWORDS: e-Agriculture, Information and Communications Technology, Framework, Agricultural Value Chain, mobile phone.

1. INTRODUCTION

In many developing countries like Nigeria, agriculture is largely traditional and practiced by smallholders and pastoralists. Characteristics of this type of agriculture are that it is predominantly rain-fed, has low-yielding production, and lacks access to critical information, market facilitation, and financial intermediation services ([DEL12]). Furthermore, in developing nations, the low availability of timely and needed information is skewed in favour of more informed individuals or organizations which often force disadvantaged farmers to sell their harvests below fair value. The uneven spread of infrastructures (roads, telecommunication, government services and so on), weak infrastructures, underinvestment in rural areas, inadequate access to markets and unfair market conditions, inadequate access to relevant technologies, high production and transport costs, and so on is equally problematic in these developing nations, leading to significant differences in the ability to leverage individual and regional strengths. Most farmers have access to a variety of information sources that they consult for regular agricultural information, even though these may not be the most up-to-date, accurate or beneficial sources. Many farmers do not have a single channel that serves as a comprehensive source for all their information needs. The most common sources are still television, radio, newspapers, other farmers, government agricultural extension services, traders, input dealers, seed companies and relatives ([MSL13]). However, the quality and relevance of the information provided by these sources can be highly variable. Some sources of information may even be biased against the farmer, such as the intermediary/trader who also serves as a moneylender. Most farmers in developing countries therefore lack access to consistent, reliable information for many of their needs and often rely on a combination of these varied but inconsistent sources, plus traditional knowledge, experience and estimates, when making decisions. Another constraint is that even when correct and timely market price information is available, farmers are often unable to exploit any potential pricing benefits that exist between markets because of their inability to transport their produce to the markets with higher prices.

Encouragingly, different ICT solutions have emerged, which are increasingly available in even the remotest locations to help overcome these information gaps and improve the business of agriculture proactively ([MSL13]). With the proliferation of affordable technology even among the poor smallholder 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 ([Q+12]). ICT arguably can increase the efficiency, productivity and sustainability of the agriculture sector, through e-Agriculture, by availing to farmers, information easily and cheaply with a view to improve farm operations, marketing and financing ([A+13]). E-Agriculture offers the rich potential of supplementing traditional delivery of services and channels of communication in ways that extend the agriculture organization's ability to meet the needs of its farmers ([NA13]). Benefits include enhanced access to information and resources, empowerment of farmers to make informed agricultural decisions, streamlined organizational processes and transactions, and improved quality, value, and agricultural productivity satisfaction. E-agriculture is now recognized globally as means of empowering farmers in making informed decisions on production and marketing of agricultural produce. It is a field focused on the enhancement of agricultural and rural development through improved information and communication processes ([MJ04]). This paper presents an e-Agriculture framework for inclusive agricultural value chain in Nigeria. Specifically, the framework presents a platform through which information on markets and market prices can be made available to rural smallholder farmers in Nigeria. 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 e-Agriculture framework; Section four present the results and Sections five summarized and concludes the paper.

2. LITERATURE REVIEW

2.1 Inclusive Agricultural Value Chain

Smallholder farmers in developing countries remain underprivileged, lacking access to critical information required for their agricultural activities. They have limited access to the inputs, support services, markets, and credit that would enable them to increase their production and sales volumes ([IIC14]). In many cases, small-holders are also vulnerable to environmental and economic shocks, subject to high transaction costs due to poor infrastructure (power, communications, roads), and are unable to fully benefit from the established good practices or the latest appropriate technological advances. Besides this, they are increasingly facing intense competition from advanced multinationals, which operate in a globalized food market to which small scale producers have very limited access. It has been proven that growth and modernisation of the agriculture sector in developing countries is one of the most effective mechanisms to alleviate poverty.

One of the approaches for agricultural development which has gained momentum is strengthening of the agricultural value chains systems which identify a set of actors and the full range of their respective activities that aim to bring agricultural products from farmers, through intermediaries, to end consumers. Within the value chain, a combination of physical transformations and inputs of various services adds value to the products at each of its intermediary stages ([IIC14]; [MSL13]; [MKJ15]):

i. Pre-production (research and development, input supply, production planning);
ii. Production (production in the field); and
iii. Post-harvest and Marketing (transport, storage, processing, packaging, certifying, distributing, wholesaling and retailing to the consumer).

Under the right conditions, smallholders can be at the forefront of a transformation in the world's agricultural systems ([IFA13]). Unfortunately, even though modern value chains can usually offer wages and self-employment with better pay and working conditions than in traditional agriculture, they can also be channels to transfer costs and risks to the weakest nodes – smallholder farmers ([FAO10]). Therefore, the purpose of the development of inclusive agricultural value chains is to safeguard the interests of the smallholder farmers, who otherwise remain at risk of profiting the least from the agricultural value chain development. The key mechanism for achieving this inclusive development is improving the ability of vulnerable small-scale producers to sustainably increase productivity, access markets and increase their income in order to allow for the long-term social benefits in their rural areas.

2.2 Underdevelopment of Inclusive Agricultural Value Chain in Nigeria and sub-Saharan Africa

Agriculture is Nigeria's single largest economic sector. It contributed 24.44% to nominal gross domestic product (GDP) as of the third quarter of 2017, ([NBS17]). Over the years, agriculture in Nigeria is increasingly becoming important as a source of consumer and industrial demand. This on one hand is due to government's renewed focus on diversification through import substitution and on the other hand, due to Nigeria's large and growing population. Though agriculture make up a reasonable portion of economic activities in Nigeria, the sector's impact on individual, government and export revenue is relatively small ([PWC17]). The reason is not farfetched: the value chain of the sector is highly

underdeveloped; focus is majorly on production, with more than 80% of farmers of the country being smallholders and few commercial processors rather than on enhancing value addition across value chain segment. Linking smallholder farmers to markets remains a major challenge in Africa and is associated with the lack of smallholder commercialization in the continent ([PDK05]; [Bar08]). A number of factors contribute to this problem.

First, smallholder farmers are usually price-takers and deal with traders who often are more informed about input and output markets. Second, majority of smallholders lack the information on quality and quantity parameters used by traders in the selling process. Lack of information prevents farmers from adopting profitable production alternatives and also keeps them supplying low-paying marketing outlets. Third, seasonal variations in prices often expose smallholder farmers to greater price risks than the larger farmers, causing the former to dispose of their produce soon after harvest. Fourth, smallholder farmers trade in small village markets with long and fragmented value chains. In addition to the above market-based (incentive) factors, smallholder farmers also encounter a number of capacity-based constraints. The majority of smallholder farmers are asset-poor ([Bar08]). They lack financial capital needed to acquire the inputs required to commercialize production, the human skills (capital) needed to function in better-paying but competitive markets and the social capital that is instrumental in organizing production ([D+04]). In addition, smallholder farmers often face poor infrastructure in form of roads, telecommunication and electricity that impede their market access. Further, smallholder farmers, given their geographical dispersion tend to be characterized by organizational failure ([RN05]). That is, majority of smallholder farmers are often unable to mobilize themselves into farmer organizations and take advantage of benefits of collective marketing such as economies of scale and collective bargaining power. Information and asset poverty make the cost of doing business that is transaction costs, unaffordable to majority of smallholder farmers ([ST07]). Consequently, such farmers prefer selling their produce in nearby village markets or at the farm rather than travelling to the market where they could get better prices ([FH08]). Such village markets however tend to offer low prices and are characterized by significant price variation ([Ake08]).

For many African countries, commercializing smallholder agriculture provides the only engine for agrarian and rural development. However, commercializing the small-scale farm sector requires efficient markets which in turn require access to market information, transparent and profitable pricing system, and capital (especially credit and better production practices). Where market information is not readily available and accessible, opportunistic behavior (by traders and other market actors) tends to develop. One such behavior is the cheating on quality and quantity (especially scale) which in turn results into the failure of traders to establish long-term business relations in Africa ([FG06]). Due to the opportunistic behavior between buyers (traders) and sellers (farmers), transactions tend to be relational (that is, selling only to those previously known and hence trusted), are in small volumes and are based on visual inspection. The tendency for transactions to involve visual inspection precludes long distance, non-personal transactions and typically increases the cost of trade (since actors must travel long distances to verify quality of traded commodity during the buying process). It also retards expansion of trade between regional and distant market actors. The prior imperfections in the markets for smallholder farmers have led to a search for alternative models of integrating such farmers into better paying commodity value chains. Encouragingly, e-Agriculture frameworks can provide a platform to address these concerns by incorporating all the stakeholders in agriculture; the core objective of which will be to provide affordable, efficient and effective media for the exchange of information and knowledge supported by ICT ([A+16]).

2.3 ICT in Agricultural Development

ICTs have been a significant contributor to growth and socio-economic development in many sectors, countries and regions where they are well adopted and integrated. It can contribute to poverty reduction, if tailored to the needs of the poor and boost economic growth. If economical and efficient media for the exchange of information, ideas and knowledge are available, ICT can become an enabling tool for wider socio-economic development ([Kev03]; [Lot 07]). But what are ICTs precisely? ICT is any device, tool, or application that permits the exchange or collection of data through interaction or transmission ([M+11]). It is an umbrella term that includes all technologies for the communication of information.

In most developing economies, ICT4 for Development (ICT4D) involves the usage of ICT as a tool to enhance development. 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, obile for Development (M4D) has emanated from ICT4D, with a keen focus on provision of mobile technology solutions in the aforementioned sectors.

The increase in affordability, accessibility and adaptability of ICTs 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 ([M+11]; [DEL12]).

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 ([Q+12]). 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 ([A+16]). 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.

2.4 Mobile Phones as Panacea for Implementation of e-Agiculture

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 ([O+13]). The penetration rates of mobile phones are outstripping those for internet users, fixed phone lines and broadband subscriptions. 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 ([ITU19]). 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 proliferation of mobile phones in Nigeria 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 ([ICT13]). 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.

Furthermore, mobile phones have the advantage over other ICT tools in terms of its appropriateness for the under-developed local conditions. It has been found to help improve the productivity of individuals and organizations within resource-constrained environments as it increases efficiency, effectiveness, and reach ([Hud06]; [Q+12]). 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), Short Message Service (SMS), Unstructured Supplementary Service Data (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.

2.5 Related Works

Many ICT interventions have been developed and tested around the world, with varied degrees of success, to help agriculturists improve their livelihoods through increased agricultural productivity, incomes and reduction in risks. Some of such interventions for market access services and financial inclusion includes:

[RF00] presented a market information system for small scale producers and traders in three districts of Uganda. The system is a pilot project targeted at providing market information for small-scale farmers, traders and processors.

[Gin05] reviewed the *DrumNet* which is a network for rurally situated farm business support centres delivering agricultural extension, credit, and marketing services to smallholder farmers with the aim of increasing their farm productivity, their access to markets, and the efficiency with which they conduct business.

[Q+12] presented the *b2bpricenow* which is a platform that provides current market price information to farmers and cooperatives in Philippines. The service links sellers to buyers and can process financial transactions using bank accounts or debit cards via a mobile phone

[Q+12] revised the *Dialog Tradenet*, a platform that forwards agricultural commodity price information by SMS and USSD, reducing information arbitrage. Subscribers receive up to five price alerts for five fruits and vegetables from each of the three markets covered. Also, it provides a trading platform for farmers to identify potential buyers.

[GL12] developed a model for designing M-Agriculture Applications for dairy farming. The model concentrates specifically on dairy farming and shows how various stakeholders (dairy farmers, milk buyers, veterinary doctors, agricultural experts and relevant government agencies) in this sector can share a mobile platform that meets their various needs.

[MKJ15] proposed a framework for accessing agricultural market information. The objective of the framework was to present a platform linking smallholder farmers to markets. The framework considers how agricultural information can increase access to markets and provide linkage to other market participants.

[War17] described the *M-Farm* which is owned by M-farm Ltd a software solution and Agribusiness Company which provides up-to-date market prices to farmers and links them to buyers through their marketplace and current agro-trends. This mobile application gives the farmers the opportunity to sell their yields collectively and also to buy farm inputs by use of mobile phones or their website. The software also provides market prices to the farmers.

[Khi17] developed an agricultural marketing information system for speedy collection and dissemination of market information and data for its efficient and timely utilization. The system also extends it functionality to facilitation, collection and dissemination of information related to better price realization by the farmers.

[Jum17] developed an agricultural market information system using the concept of crowdsourcing which allows farmers to broadcast available produce for sales and also allows buyers to submit their requests using SMS or web.

A comparison amongst the reviewed related work and the present research work is detailed in Table 1.

3.METHODOLOGY

Finding appropriate research methodologies is critical in drawing up model solutions/ systems to identified problems ([FKN94]) This paper applied the Systems Development Life Cycle (SDLC) approach to derive an e-agriculture framework that would solve a real life problem. The SDLC in systems engineering, information systems and software engineering, is the process of creating or altering systems, and the models and methodologies that people use to develop these systems ([PA06]).The phases involved in evolving the e-agriculture framework are:

a) **Requirements definition:** The development of any e-Agriculture framework requires the understanding of the current sources of information or services that are utilized by the population being targeted by the e-Agriculture intervention. Other factors of importance to consider would be their literacy levels, language proficiency, technical capabilities and the technologies available to them. In this work, of utmost importance in the design were the considerations for:

Table 1: Comparison of Related Works

Author(s)	Name of System/ Framework	Services and Support	Communication Channels
[RF00]	*Market Information System*	Market Information	Radio, Voice and Web
[Gin05]	*DrumNet*	Markets, Market Information, Logistics, and Credits	SMS and Web
[Q+12]	*b2bpricenow*	Markets and Market Information	Web
[Q+12]	*Dialog Tradenet*	Market Information	SMS and USSD
[GL12]	*M-Agriculture Applications*	Markets	Web
[MKJ15]	*e-Agriculture Framework*	Markets and Market Information	Web
[War17]	*M-Farm*	Markets and Market Information	Web
[Khi17]	*Agricultural marketing information system*	Market Information	Web
[J+17]	*Agricultural marketing information system*	Markets	SMS, Web
This research work	*e-Agriculture Framework*	Markets, Market Information and Logistics	IVR, SMS, USSD and Web

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 information on markets and market prices can be easily accessible and available for smallholder farmers.

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 farmers. 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. IVR, SMS and USSD were employed as they are relatively affordable.

b) **Framework Design:** The framework design was done to determine applications architectural framework. The emerging framework from this design process is a representation of the structure for the realization of the defined goal. The framework will comprise of models.

c) **Infrastructural model architecting and development:** Models will be developed on the framework. The models are graphical model developed using unified modeling language (UML).

d) **Applications Development:** Applications were developed and deployed to test the framework. The applications are developed using HTML 5, PHP v6, JavaScript, MySQL server 2012, HTTP SMS gateway, HTTP USSD gateway and Voice XML.

e) **Testing**: The developed framework was tested by by experimental usage to ascertain the efficacy of the developed framework.

4. RESULTS AND DISCUSSION

Figure 1 depicts the developed e-Agriculture framework. The framework is a user-centric mobile (IVR, SMS and USSD) and web-based platform that coordinates and links farmers, buyers, financial intermediaries and logistics. The framework presents a platform via which farmers which are the targets for inclusion in the agricultural value chain can have easy and cheap access to information on markets and market prices. Information flow up and down the supply chain during crop cycle is by the use of IVR, SMS, USSD and the web.

In using the framework, farmers are required to register their particulars on the platform via any of the three mobile 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. Similarly, buyers accessing services on the framework are also required to register their credentials via any of the three mobile channels or the web. The broker, which is a third party stakeholder in the developed framework, provides information on available produce at designated markets; negotiation of market prices,

coordination of produce aggregation, grading and transportation of produce through agreements with transporters. For large scale buyers, the broker negotiates contractual arrangements between farmers and buyers during the planting season on what to plant by the farmer, and at harvest time and facilitate logistics. Communication with the framework by the broker is by any of the three mobile communication channels. The agribusiness experts post responses and answers to requests and questions from farmers and buyer based on the broker's information on markets and market prices. Also, the agribusiness expert posts advisory on agricultural market information. All documentations, managements and payments are processed by the system administrator using the web. The communication infrastructures provided by mobile network operators and the applications developed on the framework links the farmers, buyers, transporters, financial institution and the system administrator through the integrated marketing and payment system.

The applications developed on the framework facilitate and tracks payments following a successful farmer-buyer transaction. Immediately after a successful transaction, required user-data are computed into the application on the framework and a set of bank account transfers are issued to pay participating farmers and transporters. All payments from buyers pass through the application developed on the framework to the bank. Market data and transaction details are made available to participating farmers.

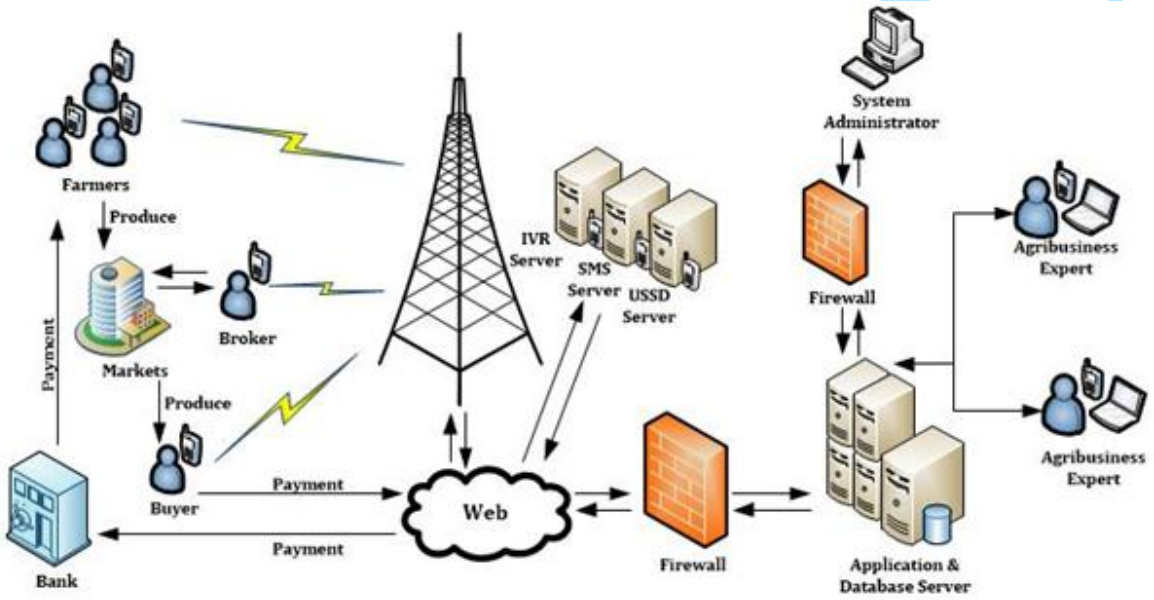

Figure 1: The Developed e-Agriculture Framework for Inclusive Agricultural Value Chains

The framework consists of components which were determined by the need of farmers, technology available to them and the technological infrastructure exposed to them. There are three communication channels for the target users (farmers) 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, USSD and web. 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 agricultural market-related information 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 agribusiness 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 agricultural market 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 farmer/buyer/broker's end of the framework. It is the medium by which the agribusiness experts review and respond to requests posed by the farmers/buyers through the aforementioned communication media. It also provides a means by which information can be broadcasted to users. Also, the system adminstrator' designations are carried out via the web.

Figures 2-6 depict the various use case diagrams showing the interaction between farmers, buyers, broker, agribusiness expert and system administrator 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.

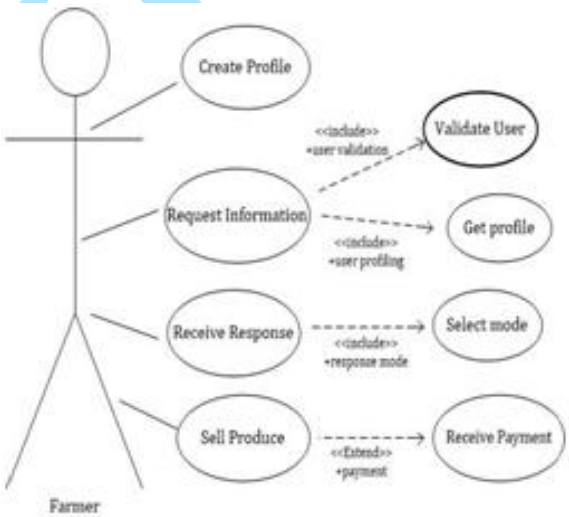

Figure 2: Use Case Diagram of the Farmer

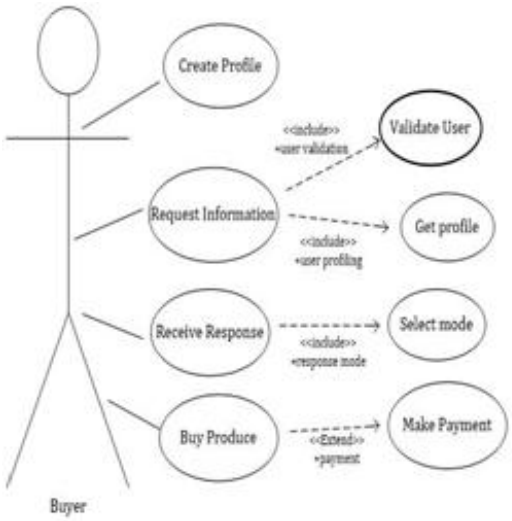

Figure 3: Use Case Diagram of the Buyer

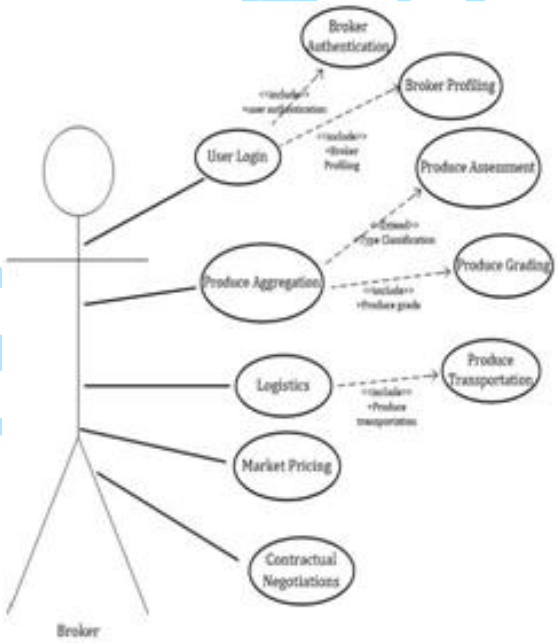

Figure 4: Use Case Diagram of the Broker

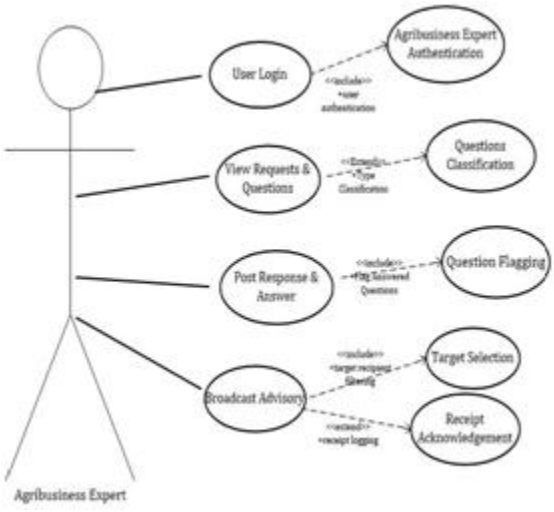

Figure 5: Use Case Diagram of the Agribusiness Expert

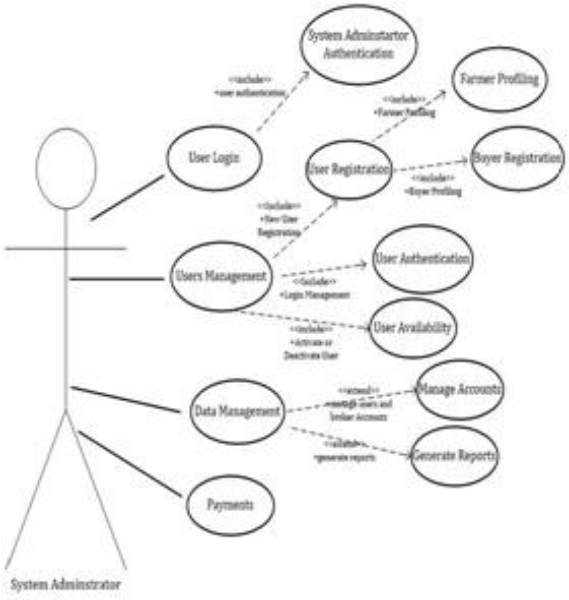

Figure 6: Use Case Diagram of the System Administrator

Sample screen shots from the implementation of framework are presented in Figures 7 to 10 below.

Figure 7: System Adminstrator Login Page

Figure 8: Agribusiness Expert Voice Request and Question Dashboard

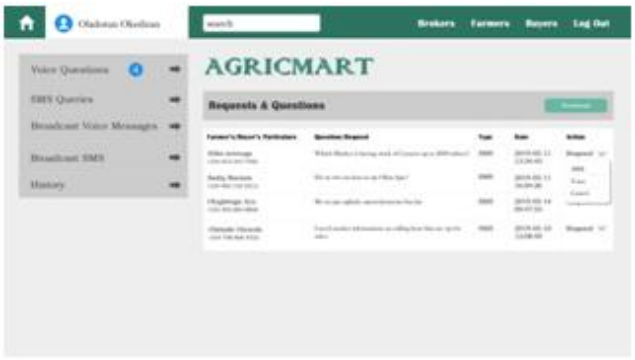

Figure 9: Agribusiness Expert SMS Request and Question Dashboard

Figure 10: System Adminstrator Dashboard

5. CONCLUSION

Agriculture is a sector that holds great promise for pro-poor economic growth. Economic growth is a key success factor for reducing poverty, but it has to be inclusive and provide opportunities for improving the livelihoods of the poor. It has been amply demonstrated that enhancing the ability of farming communities to connect with knowledge banks, networks and institutions via ICTs can improve their profitability substantially. However, in Nigeria and most of other sub-Saharan African country there exist information asymmetries along the value chain in which farmers are at the greatest disadvantage. This is owing to: poor access to agriculture-related information, deficits in physical infrastructure, digital divides, low literacy level, to mention but a few.

With increasing proliferation of affordable technology even among the poor small holder farmers, there is an immense opportunity to use ICT to provide useful information and generally empower these farmers. This work leveraged on the use of mobile phone as an ICT tool in developing an e-Agriculture framework with the aim of the improving inclusive agricultural value chains in order to safeguard the interests of the smallholder farmers, who otherwise remain at risk of profiting the least from the agricultural value chain development.

The framework presented a platform that coordinates and links farmers, buyers, financial intermediaries and logistics. Most importantly, the framework

presented a mean whereby farmers have increased access to information on markets, market prices, logistics and financial services.

REFERENCES

[Ake08] **Aker J. C. –** *Does Digital Divide or Provide? The Impact of Mobile Phones on Grain Markets in Niger*. BREAD Working Paper 177, 2008.

[A+13] **Awuor F., Kimeli K., Rabah K., Rambim D. –** *ICT Solution Architecture for Agriculture*. IST-Africa 2013 Conference Proceedings Paul Cunningham and Miriam Cunningham (Eds) IIMC International Information Management Corporation, 2013.

[A+16] **Awuor F., Raburu G., Onditi A., Rambim D. –** *Building E-Agriculture Framework in Kenya*. Journal of Agricultural Informatics, 7(1), pg 75-93, 2016.

[Bar08] **Barrett C. B**. **–** *Smallholder market participation: Concepts and Evidence from Eastern and Southern Africa*. Food Policy 33 299–317 ScienceDirect, Elsevier, 2008.

[DEL12] **Deloitte** – *eTransform Africa: Agriculture Sector Study Sector Assessment and Opportunities for ICT*. Deloitte, 2012.

[D+04] **Dorward A., Kydd J., Morrison J., Urey I. –** *A Policy Agenda for Pro-poor Agricultural Growth*, World Development 32 (1): 73–89, 2004.

[FG06] **Fafchamps M., Gabre-Madhin E.** – *Agricultural Markets in Benin and Malawi*. African Journal of Agricultural and Resource Economics 1(1) pp 67-94, 2006.

[FH08] **Fafchamps M., Hill R. V. –** *Price Transmission and Trader Entry in Domestic Commodity Markets*. Journal of Economic Development and Cultural Change, The University of Chicago Press Journals, 56 (4) pp. 729-766, 2008.

[FKN94] **Finkelstein A., Kramer J., Nuseibeh B. –** *Software Process Modeling and Technology*, Research Studies Press Ltd. Taunton, Sommerset, UK, 1994.

[FAO05] **FAO** – *Addressing Marketing and Processing Constraints that Inhibit Agrifood Exports*. A guide for Policy Analysts and Planners, FAO Agricultural Services Bulletin 60, Rome, 2005.

[FAO10] **FAO** – *Agricultural Value Chain Development: Threat or Opportunity for Women's Employment?*. Available at http://www.fao.org/3/i2008e/i2008e04.pdf, 2010.

[Gin05] **Giné X. –** *DRUMNET Case Study*. The World Bank. Available at http://siteresources.worldbank.org/DEC/Resources/Drumnet Case Study .pdf, 2005.

[GL12] **Gichamba A., Lukandu I. A. –** *A Model for Designing M-agriculture Applications for Dairy Farming*. The African Journal of Information Systems, 4(4), 2012.

[Hud06] **Hudson H. –** *From rural village to global village: Telecommunications for development in the information Age*. Danbury, CT: Lawrence Erlbaum, 2006.

[ICT13] **ICT Updates –** *e-agriculture strategies* issue 73, August 2013. Available at https://cgspace.Cigar.org/bitstream/handle/10568/75314/ICT073E_PDF.pdf?sequence=1&isAllowed=y, 2013.

[IFA13] **IFAD –** *Smallholders, Food Security, and the Environment*. International Fund for Agricultural Development, Rome, available at https://www.ifad.org/documents/ 38714170/39135645/ smallholders_ report .pdf /133e8903-0204-4e7d-a780-bca847933f2e, 2013.

[IIC14] **IICD –** *ICT Solutions for Inclusive Agricultural Value Chains*. International Institute for Communication and Development, The Hague, 2014.

[ITU19] **ITU** – *Mobile Cellular Statistics*. International Telecommunications Union: - https://www.itu.int/en/ITU-D/Statistics/Documents/statistics/2018/Mobile_cellular_2000-2017_Dec2018.xls, 2019.

[J+17] **Juma M. F., Fue K. G., Barakabitze A. A., Nicodemus N., Magesa M. M., Kilima T. M., Sanga C. A. –** *Understanding Crowdsourcing of Agricultural Market Information in a Pilot Study: Promises, Problems and Possibilities (3Ps)*. International Journal of Technology

diffusion, IGI Global, Pennsylvania, USA 8(4) 2017, pp 1-16, 2017.

[Kel03] **Kelles-Viitanen A. –** *The role of ICT in poverty reduction*. The Finnish Economy and Society, 82-94, 2003.

[Khi17] **Khizer S. –** *Agricultural Marketing Information System – Architecture, Framework and Model*. International Journal of Computer Technology and Applications, 8(3),370-374, India, 2017.

[Lot07] **Lotter H. –** *Are ICTs Prerequisites for the Eradication of Poverty?*. International Review of Information Ethics, 7(9), 2007.

[MJ04] **Meera S., Jhamtani A. –** *Information and Communication Technology in Agricultural Development: A Comparative Analysis of Three Projects from India*, 2004.

[MKJ15] **Mawazo M. M., Kisangiri M., Jesuk K. –** *Toward a Framework for Accessing Agricultural Market Information* The Electronic Journal of Information Systems in Developing Countries, 66(3), pp1-16, 2015.

[MSL13] **Miller C., Saroja V. N., Linder C. –** *ICT Uses for Inclusive Agricultural Value Chains* FAO, Rome, 2013.

[M+11] **Mcnamara K., Belden C., Kelly T., Pehu E., Donovan K. –** *Introduction: ICT in Agricultural Development*, ICT in Agriculture, The World Bank, p3-14, 2011.

[NA13] **Namisiko P., Aballo M. –** *Current Status of e-Agriculture and Global Trends: A Survey Conducted in TransNzoia County, Kenya* - Volume 2 Issue 7 pp 18-22 International Journal of Science and Research, India available at https://www.ijsr.net/archive/v2i7/MTIwMTMxNA==.pdf, 2013.

[NBS17] **NBS –** *Nigerian Gross Domestic Product Report (Q3 2017)*, National Bureau of Statistics, available at http://www.nigerianstat.gov.ng/download/678, 2017.

[O+13] **Okediran O. O., Omidiora E. O., Olabiyisi S. O., Ganiyu R. A. –** *An M-voting System Framework for Electronic Voting*, Proceedings of the Second International Conference on Engineering and Technology Research, Lautech, Ogbomoso, Nigeria, 2013.

[PA06] **Post G., Anderson D. –** *Management information systems: Solving Business Problems with Information Technology*, New York: McGraw-Hill Irwin, Fourth edition, 2006.

[PDK05] **Poulton C., Dorward A. Kydd J. –** *The Future of Small Farms: New Directions for Services, Institutions and Intermediation*. Paper presented at the IFPRI / ODI / Imperial College London: Future of Small Farms Research Workshop, Wye, UK 82 June 26-29th 2005, available at http://www.ifpri.org/events /seminars/ 2005/smallfarms /sfproc/ SO6_Poulton.pdf., 2005.

[PWC17] **PWC –** *Transforming Nigeria's Agricultural Value Chain: A Case Study of the Cocoa and Dairy Industries*. Pricewaterhouse Coopers Limited, Nigeria, 2017.

[Q+12] **Qiang C. Z., Kuek S. C., Dymond A., Esselaar S. –** *Mobile Applications for Agriculture and Rural Development*, ICT Sector Unit World Bank, Washington D.C., 2012.

[RF00] **Robbins P., Ferris S. –** *Design of a Market Information System for Small Scale Producers and Traders in Three Districts of Uganda*. Study report CTA number 8019, IITA/Foodnet Project, 2000.

[RN05] **Rich K. M., Narrod C. A. –** *Perspectives on Supply Chain Management of High Value Agriculture: The Role of Public-private Partnerships in Promoting Smallholder Access*. 2005.

[ST07] **Shiferaw B., Teklewold H. –** *Structure and Functioning of Chickpea Markets in Ethiopia: Evidence Based on Analyses of Value Chains Linking Smallholders and Markets*. IPMS Working Paper 6. Nairobi, Kenya, 2007.

[War17] **Warwimbo J. W. –** *Information and Communication Technology (ICT) and Value Chains in Agribusiness*. Unpublished Masters' degree dissertation, University of Nairobi, 2017.