

Review

The use of Information Communication and Technology in advancement of African agriculture

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Food security in Africa continues to be a big challenge and one of the key constraints is lack of information on many facets of agricultural research and development to the key sector stakeholders. However, in recent years a wide range of Information Communication and Technology (ICT) platforms and mechanisms have been used across Africa in enhancement of exchange of agricultural related information for increased productivity and improvement of marketing of crops and livestock products. The purpose of the review paper was therefore to assess the nature, diversity and impacts of ICTs used in African agriculture and also highlight the key challenges hindering more widespread use of the technologies. A Kenyan case study has been used to typify the integrated nature of ICTs use in agriculture. The paper reveals that there is a very wide range of ICTs being used and these include web portals, mass media and different types of mobile telephone based services. Of all the ICTs, the radio service is the most effective in reaching a wide cross-section of agricultural research and development fraternity. It is evident that ICTs are making impact in increasing productivity and marketing of products but there are still several constraints including unconducive policy environment, insufficient communication infrastructure and inadequate farmer level capacities to use available ICTs. Public policy should therefore address these challenges and constraints within the sphere of rural development in general and agricultural productivity in particular. The review concludes that when mobile phones are combined with other ICT platforms such as mass media, the impact on agriculture is likely to be very high.

Key words: Information Communication and Technology (ICTs), African agriculture, agricultural research and development, mass media, mobile telephones.

INTRODUCTION

Information and Communication Technologies (ICTs) is a convergence of telecommunication and computing technologies for acquisition, retrieval and dissemination of information. It generally refers to the growing assembly

of technologies currently being applied in facilitated communication and handling of information in different economic sectors. These technologies include computer software and hardware, CD-ROMs, radio, telephone,

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email, internet, television, videos and digital cameras as well as processing, storage, transmission and presentation of information in different formats such as texts, images, voice and data (Asenso-Okyere and Mekonnen, 2012; Aina, 2004). These platforms allow for the acquisition, processing, storage, sharing as well as information dissemination among humans and computers, locally and globally. The various ICTs enable the agricultural sector to benefit from increased flow of information to its stakeholders in a cost-effective manner. In the last two decades, the increased use of mobile telephones, the internet as well as personal computers has provided a diversity of choices in collection, storage, processing, transmission and presentation of information in various formats in response to different needs and user requirements (Asenso-Okyere and Mekonnen, 2012).

The agricultural sector is the source of livelihood for a great majority of the 75% of the people living in rural areas in Africa (OECD, 2016). Africa's agricultural sector has witnessed a notable decline over the past 40 years yet food security is critical for the survival of individuals, households and ultimately nations. According to World Bank (2010), 73% of the African people live in rural areas surviving on less than a dollar a day and poor farmers have largely remain poor. Just like in other sectors, African agriculture is faced with a number of challenges and constraints which include insufficient investment in rural areas, inadequate advanced appropriate technologies and inputs including improved varieties as well as inadequate access to markets and unbalanced market conditions, among other things. Agriculture in Africa is predominantly rainfed and is characterized by low yields and productivity, poor market facilitation as well as lack of access to financial intermediation services and other related critical information (World Bank, 2010).

Potentially, ICT can play a significant role in addressing some of these challenges since there is now an increased availability and use of such personal ICT devices as computers, mobile phones and tablets. The mainstreaming of ICT in agricultural stakeholder systems could spur economic development and growth by bridging critical knowledge gaps and increasing access to improved varieties and other technologies as well as the related information. One of the most widely used ICT is mobile technology, which is rapidly being adopted as the technology of choice in the delivery of agricultural related ICT services and solutions (Martiz, 2011). The main beneficiaries of the wider adoption of ICT in agriculture are five stakeholder groups which include agricultural businesses, farmers and farmers' associations, researchers, government ministries and citizens at large.

Over the years, the use of ICTs in African agriculture has increased considerably (May et al., 2007; Munyua, 2008). The application of ICT in agriculture, the largest economic sector in most African countries, provides great opportunities for poverty alleviation as well as the continent's economic growth (Christoplos and Kidd,

2000). In Africa, ICTs are complemented by social systems and/or networks which are instrumental in the sharing of knowledge. For example, a few available mobile phones can be used to spread a message quickly from an authentic source to different communities as well as members of a community including clans, solidarity association members and households. When combined with radio, mobile telephony enables transmission of messages to a large number of listeners. Some African communities have even tried the use of knowledge management web portals for the access of production and marketing information, albeit with some challenges. It is also evident that the technology is being used effectively for dissemination of information on weather forecasts, market prices, transport, storage facilities, livestock and crop diseases as well as general advice on agriculture (Gakuru et al., 2009). Studies conducted in several countries, have revealed that there is a positive correlation between investment in ICTs such as internet, fixed-line, mobile telephone or broadband penetration and Gross Domestic Product (Qiang and Rossotto, 2009; Verdier-Chouchane and Karagueuzian, 2016). The reported returns on ICTs investment include development of the private sector, increased trade competitiveness and innovation as well as job creation and poverty reduction (Adera et al., 2014; Chavula, 2014). Though some information on the use of ICTs in African agriculture is available, documentation is not comprehensive enough. The purpose of the review paper was therefore to assess the nature, diversity and impacts of ICTs used in African agriculture through document analysis, published and grey literature, case studies website information extracts. The paper also aims at highlighting the key challenges hindering more widespread use of the technology in the African continent.

METHODOLOGY

The overall philosophical approach was inductive and interpretive through literature review and document analysis. The literature review was conducted according to procedures established by Okoli and Schabram (2010). It was a stepwise process that started with defining the research topic and understanding the concept of 'broader' and 'narrower' terms. Narrowing the topic made it easier to limit the number of sources that needed to be read in order to get a good survey of the literature. This was followed by literature review, document analysis, collation and synthesis of information as well as report compilation. The methodological flowchart is provided in Figure 1.

The most relevant sources of the literature for the topic were identified and these included books, journals and institutional documents that contained useful and relevant information. This was supplemented with information from internet sites, institutional websites, web portals, project reports, theses and dissertations, conference papers, ePrints and government or industry reports. Ebsco Host, Emerald and Jstor journal databases were searched for relevant information using wildcards and logical brackets. Information sources were then grouped into themes and subthemes of the research topic. The literature review was supplemented with information retrieved through document analysis, which was used

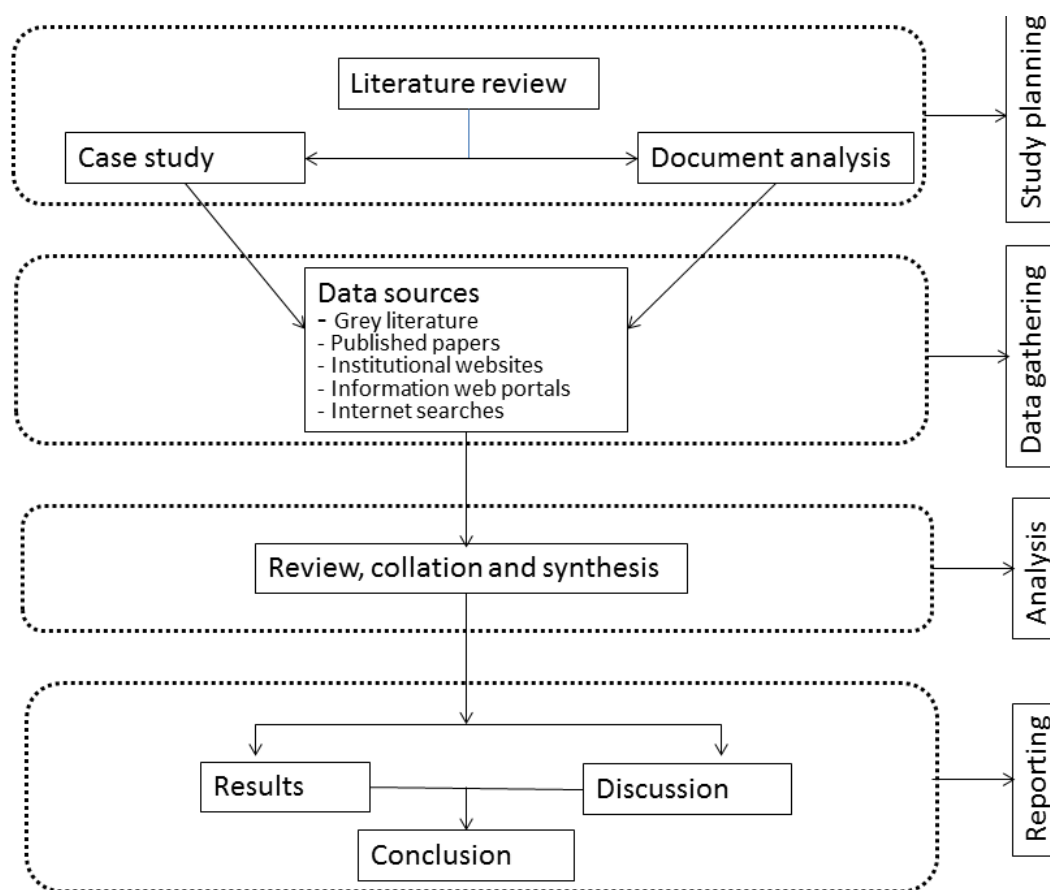


Figure 1. Research methodology flowchart.

as a form of qualitative research in which documents were interpreted to extract relevant information and data on the topic (Bowen, 2009). This involved analyzing documents from publicly available records and coding content into themes as guided by Bowen (2009) and O'Leary (2014). The information from literature review and document analysis was then collated, synthesized and analyzed to develop the results and discussion component of the review. In the analysis, several factors were considered and these included the subjectivity of the authors and also the personal biases they may have brought into the research; evaluation of the original purpose of the document, such as the target audience; latent content, which refers to the tone, style, agenda, facts or opinions that exist in the document and assessment of their completeness, particularly the selectivity or comprehensiveness of the data (Bowen, 2009).

RESULTS AND DISCUSSION

ICT platforms being used in African agriculture

The study revealed that there is a wide variety of ICT platforms that are currently being used to provide, exchange and disseminate different types of information and technologies to farmers and other agricultural research and development stakeholders in Africa. These include online PC based platforms, internet websites, mobile telephones, radios, TV's and GIS tools among

others (May et al., 2007)

There is a wide range of websites and online portals providing interaction platforms for agricultural research and development information. A good example is the Africa Trial Sites (<http://africats.org/>) which was established upon the recognition that the variability of African growing conditions hindered the widespread adoption of high yielding and stress resistant varieties. This variability also contributed to difficulties in selection of appropriate testing sites for improved varieties and matching them to appropriate growing environments throughout the continent. This portal makes it possible for both international and national research organizations to pool their information on trial sites electronically. It also provides a wide range of tools that are based on ICT advances in GIS, bioinformatics as well as data management in order to enable plant breeders, agronomists and farmers to acquire more useful data from field trials through the efficient field evaluation of improved varieties. The portal has a lot of the data from field trials and research conducted over many decades and for some time was held in the shelves of research institutions, making it difficult to assemble, analyze on a large scale and utilize. In addition, it allows users to browse the website for trial sites and other data on a

country basis, design trials for cultivar evaluation, access tools for trials management, trial data analysis, viewing of spatial analyses results, examination of data on an interactive google map and online reporting of results.

It is also possible for portal users to rank varieties and give comments on their performance at any given site. Through the website, climate data for any point in Africa can be analyzed and comparison of climate similarity between trial sites and other areas in Africa can be made. Finally, the site provides links to a variety of resources including websites of the participating institutions where users can request seed from gene bank curators and breeders. The combination of interactive data analysis tools and data from trial sites has made it possible for valuable information to be more widely available for use by stakeholders in agricultural research, development and extension. Although some results for improved varieties evaluated in Africa are available online, more data from researchers could significantly increase knowledge on the suitability of varieties to different environments, particularly those that are susceptible to diseases, pests or environmental stresses. The trial sites are now being used by international agricultural research centers in a climate adaptation research program that draws in national partners and using Africats.org for standardization of the information from trial sites (World Bank, 2011).

Mobile communications technology is another platform that is rapidly becoming one of the most widely used channels of transmitting voice, data and related services for use in a wide variety of economic sectors in Africa (Martiz, 2011). In light of this remarkable change, the potential for advancing development is significantly increased by mobile applications (m-apps) in general and mobile applications for agricultural and rural development (m-ARD apps) in particular. The focus of most of the m-ARD apps is to improve agricultural supply chain integration and they normally have a wide range of functions, including provision of market information, facilitation of market links and improving access to extension services. The users of these apps are diverse and they include buyers of farm produce, farmers, input suppliers, cooperatives, content providers and other stakeholders in the agricultural sector. A good example of the use of these apps is in Zambia, where “e-voucher” which is an electronic voucher system has been piloted by CARE, the United Nations World Food Program (WFP) and the local Conservation Farming Unit (CFU). Mobile Transactions, a company that specializes in low-cost payment and financial transaction services (<http://www.mtzl.net/>) supports the e-voucher system to empower smallholders in obtaining subsidized inputs from private firms. This, in turn, gives the firms an incentive to improve and expand their business. In addition, the e-voucher system provides support to private agribusinesses by allowing them to be the direct source for inputs and competition increases as more

private input dealers participate (World Bank, 2011). This system can also be used to access varieties and the related information as key inputs supplied by agro-dealers.

The use of ICT based agricultural products market platforms is slowly gaining pace in Africa. Since markets as well as market information are available, farmers have the opportunity to use the information to make informed choices about marketing and also improve their incomes by bargaining. They can also seize market opportunities by adjusting production plans and allocating production factors better. In this regard, ICT based market platforms are playing a crucial role by providing timely and relevant information in a manner that makes it easy to be absorbed and acted upon immediately. The services provided by these platforms are usually easy to understand, subscribe to and use. This makes them an excellent point of entry for more information services, such as general agricultural education and long-term extension services (May et al., 2007). For example in Ethiopia, ICT based market platform is enabling real time transmission of commodity price information to farmers by the novel Ethiopian Commodity Exchange (ECX). (World Bank, 2011) states that market data is transmitted to farmers through electronic display boards that are located in 31 centers across Ethiopia and also on the ECX's website. This data is also provided through text messages to interested mobile phone users. It is also provided in four local languages through automatic telephone messages. The service is in high demand and close to 20,000 calls by users seeking for price information are made daily through a toll free number World Bank (2011). Similarly, the Kenya Agricultural Commodity Exchange (KACE) and the Malawi Agricultural Commodity Exchange (MACE) also have ICT based commodity exchange services which include bids and offers that are displayed prominently on blackboard and also disseminated through text messages as well as internet. For instance, KACE gathers, updates, analyses and provides timely and reliable market information as well as intelligence on a wide range of crops commodities. The exchange platform targets actors in commodity value chains, mainly focusing on small scale agribusinesses and smallholder farmers (KACE, 2011). The exchange platform harnesses the advantages of modern ICTs and its power to collect, process and deliver market information using its effective Market Information and Linkage System (MILS). Moreover in Kenya, smallholder farmers also receive market information through text message and this enables them to have access to daily agricultural commodity prices. Text messages are also used to send extension related information and also in selling of commodities or bidding for their prices. Farmers are also connected with buyers in different urban centers through rural-based market information points that are linked to an electronic information system (KBDS, 2004; Muriithi et al., 2009;

Davis and Addom, 2010).

The agricultural marketing service (SIMA) in Mozambique uses a variety of ICTs including email, text messages, national and rural radios, internet as well as television and newspapers to collect and disseminate provincial and nation-wide data on product processing, availability and market prices. Available reports from CTA (2006) and Jenson et al. (2004) reveal that farmers usually obtain higher farm prices when they have access to market information. Similarly, the use of ICTs in Uganda has greatly enhanced exchange of agricultural related market information. For example, the Grameen Foundation has developed a comprehensive SMS-based system that enhances delivery of market information to farmers (Pyramid Research, 2010). Since 2008, the Foundation has also been using such programs as Application Laboratory to test new uses of the village phone infrastructure and then launched a series of mobile phone applications for dissemination of market information in 2009. This technology was developed in partnership with Google and MTN Uganda. It leverages MTN's network of village phones and a total of 35,000 public-phone operators in testing and delivery of mobile information services to rural communities. Moreover, the Grameen Foundation has trained and established a network of community knowledge workers (CKWs) which serve as "knowledge hubs" for smallholder farmers in Uganda. The hubs give the farmers online advice and information on diverse agricultural activities. All these services are based on text messaging and are designed for use with basic mobile telephones in order to reach the widest possible audience. The services can usually be accessed through existing village phone operators, who provide the service to farmers without mobile phones. The farmers send their queries and then receive the answers later (Pyramid Research, 2010). Similarly, in Kenya, a pilot project called Banana information line, has been using text-to-speech (TTS) telephone service in either English or Kiswahili to provide farmers with information on planting, growing and harvesting of bananas. Recently, this was superseded by the National Farmers Information Service (NAFIS) which covers a wide range of livestock and crops. Through the service, the country's farming community receives and exchanges timely information and news on weather patterns, agriculture and related issues through mobile telephones (Gakuru et al., 2009). Radio services are also a widely used communication technology in dissemination of agricultural information. A good example is the Farmer Voice Radio (FVR) which is a radio extension service that targets smallholder farmers in Ghana, Kenya, Malawi, Mali, Tanzania and Zambia. The FVR extension agents provide on-site extension support on regular basis to a small group of pre-selected farmers. The information and experiences are then documented and broadcast via radio (Payne et al., 2010a). In Tanzania, community radio stations are now incorporating mobile technology into

programming for use in advisory services in agriculture. The approach is building on the utility of mobile telephones as recording tools and listening devices (Gakuru et al., 2009). The acquired information is then used or shared in many ways. For instance, the farmers living near the radio station can obtain information directly by walking in to enquire, ask questions or report issues related to agriculture and farming. Farmers also have the option of listening to information and agricultural related news over the radio. The radio stations have also developed an SMS messaging system for sending and receiving information on a wide range of agricultural issues.

In west Africa, there are several examples of use of ICT in agricultural research, development and marketing. For instance, Manobi in Senegal collects price data on various crops from different markets across the country and provides this information to a wide variety of users. Mobile phones are used to send the price data to the Manobi database via wireless application protocol (WAP) and farmers then query the database using their mobile phones (ITU, 2010b). These mechanisms can potentially be used for a wide range of services including varietal availability and related information. Similarly, the Market Information Systems and Traders' Organizations of west Africa (MISTOWA) has partnered with the private sector to develop a platform (www.tradenet.biz) that enhances real time exchange of market information on-line or through mobile phones. The system uses text messages for relaying information on market prices, sales and purchase offers as well as trader contact information for ease of business links. The system also provides producers and trader organizations with online space to create websites for dissemination of their business related information (Davis and Addom, 2010).

In Nigeria, the Integrated Cassava Project disseminates market information to cassava growers through the internet, mobile phone and online market place platform called Trade Net Africa. The platform disseminates market information through the Agri-Business Information Points (market information centers) as well as trade agents. The services provided include market information such as prices, demand volumes and offers. They also include assistance in trade and market trends, training, SMS alerts and technical messages on different aspects of agricultural products marketing (Pyramid Research, 2010). In Ghana, a local company called Esoko has developed ICT based services that include placement of purchasing and selling orders by both farmers and traders. The service is supported and complemented by a network of agents who collect information on prices of about 20 agricultural commodities from 30 in-country markets. The company has a system of providing information on commodity prices to farmers and other stakeholders on a subscription basis (Martiz, 2011). Further experiences from Ghana demonstrate the power of mobile phones in

obtaining and providing production and marketing information to cocoa farmers. For instance, the Ghana Cocoa Board has launched a pilot program called Cocotalink. This is public-private partnership between the World Cocoa Foundation and Orange which provides cocoa farmers with useful information on prevention of crop diseases, post-harvest production, marketing of crop products, farm safety and improvement of farming practices. Through the program, specific answers to questions and agricultural related information are sent to farmers by both voice and text messages in English or in their local languages free of charge (Martiz, 2011). This program enlisted 3,700 users in Ghana by the end of 2013 (United Nations, 2014) and aims to access 100,000 cocoa farmers in Côte d'Ivoire, since it is known that there are over one million Ivoirians engaged in cocoa production in the country (Grow Africa Secretariat, 2014).

There are other forms of ICTs such as GIS, Remote Sensing (RS) and satellite imagery which are useful in land selection by facilitating the process of land registration and allocation as well as enhancing tenure security for farmers to leverage their assets (WEF et al., 2015). These ICTs are increasingly being used to ensure more efficient land use and water management. In some countries such as Cameroon, for instance, GIS systems are being used to register land before implementing redistribution mechanisms (WEF et al., 2015). In addition, GIS in combination with RS has been used in supporting the assessment of soil conditions, land capability, flood and drought risk, crop condition and yields, pest infestation and groundwater contamination (Wilson, 2005). Egypt for instance has developed a soil and terrain database for the Sinai Peninsula as well as other regions (WEF et al., 2015). In Ethiopia and Mozambique, satellite imagery data and GIS have also been used in crop inventories and facilitating land registration (Deloitte, 2012).

Use of ICT in agriculture: Kenyan case study

Agriculture is an important sector in Kenya's economy and its growth is critical to the country's social as well as economic development. The direct contribution of this sector is about 26% of Gross Domestic Product (GDP) while it contributes another 27% through linkages with distribution, manufacturing and service related sectors (GOK, 2010). Close to one-third of the country's agricultural produce is exported, accounting for 65% of the total exports. The agricultural sector employs about 80% of the country's labour force and it generates 60% of foreign exchange earnings. It controls 40% of the government earnings and provides 75% of industrial raw materials (GOK, 2007, 2010). However, the agricultural sector is characterized by low crop productivity, limited marketing opportunities and inadequate access to appropriate technologies by farmers, particularly seeds

and related inputs (GOK, 2003). Just like other sectors of the economy, agricultural development depends on access to information as an important prerequisite for crop production, processing and marketing (Jones, 1997).

In Kenya, the framework for sharing agricultural information through implementation systems is provided by the E-government Strategy, the National ICT Policy, Vision 2030 and the Strategy for Revitalising Agriculture (SRA) (GoK, 2007, 2010, 2016). Recently, E-Agriculture has emerged as a new field that focuses on enhancing rural and agricultural development through improved information and communication processes. In particular, e-Agriculture comprises conceptualizing, designing, developing, evaluating and applying innovative approaches of using ICT in the rural settings, primarily focusing on agriculture. ICT is being used in diverse ways to enhance agricultural research and development in Kenya. There are various ICT strategies and platforms being used to receive and provide information to the agricultural community as next outlined.

Mass media

Studies conducted by Rogers and Nichoff (2002) and Nabutola (2014) revealed that mass media is an important channel for communicating and conveying agricultural information. The studies also revealed that the radio is the best medium of spreading agricultural information, provided chain agents maintain close follow-up to assure farmers of the integrity of the information disseminated to them. In Kenya, the mass media programs being used include:

Mali Shambani: This is a one hour long weekly radio program produced by the Kenya Broadcasting Corporation radio station (www.kbc.co.ke). The program features agricultural related news and responds to various issues such as farming methods, market prices and trends, weather patterns and seasonal issues, agricultural inputs, financial opportunities, land use and quality standards. The weekly program comprises an interactive call-in service that allows farmers to send agricultural questions to a panel of experts by text messages or phone. An impact assessment on this service by Nabutola (2014) found out that it was very effective in reaching farmers across the country.

Shamba shape up: This is a weekly TV and radio program that provides a wide range of information on agricultural technologies including seed varieties and their sources. The program has recently included iShamba which is a subscription based sms service that farmers can use to get agricultural related information from agronomists and other agricultural experts. The information that is provided includes weather alerts,

seeds and seed sources, pests and diseases as well as market price information. The advice is tailored to the crops of interest, agro-ecology and in line with the region's crop cycle (www.shambashapeup.com).

Seeds of Gold: This is a weekly pullout in the Daily Nation, the country's most widely read newspaper published by Nation Media Group (NMG) (www.nationmedia.com). The pullout aims at enhancing farmers' knowledge in best practices for farming as well as transference of new innovations and technologies from different diverse sources to farmers. The information is wide ranging and includes crop varieties that have been recently released.

Soko Hewani: This is a radio service where bids and offers are announced on the Soko Hewani program mainly targeting farmers and agricultural small and medium size enterprises (SMEs). During the radio program, the listeners who are mostly smallholder farmers and agricultural SMEs, call in or send IVR, e-mails and text messages to bid on the offers or give offers on bids. The Soko Hewani radio broadcast staff on standby then use mobile phone calls and text messages to match the offers and bids. They may also reference back to the specific person who submitted the offer or bid in order to negotiate further and conclude the deal (www.sokohewani.com).

Mobile telephone platforms

Mobile telephones are increasingly being used because of their wide reach and usage in rural areas where farmers are domiciled. They provide a fast mechanism of creating "contact" with farmers and extension workers. Extension workers answer questions from farmers on telephone on the spot. Mobile phone technology has been used to provide a wide range of services in the agriculture sector. This includes information and analysis of commodity and stock market price, collection and dissemination of meteorological data, agricultural extension advisory services, information on prices and sources of inputs (seeds, chemicals and fertilizers), financial services, early warning systems for disaster prevention and control, gathering of agricultural statistical data and traceability of agricultural products. The mobile telephone platforms include the following:

Phone-based voice messages: The service is provided by the National Farmers' Information Service through the Local Language Speech Technology Initiative. Through this initiative, farmers living in remote rural areas receive information on crops and inputs, livestock production, market prices, disease outbreaks and weather reports. They also receive information on crop suitability for specific areas and this is very helpful as most of the farmers are illiterate and don't have access to the internet

or extension services. Through the service, text-based information is converted to audio messages, in either English or Swahili. It is then transmitted and provided to farmers over a landline telephone or cell phone. The staff of the service respond to farmers' queries by reading the relevant information back to them (Tucker and Gakuru, 2009).

iKilimo: This is a mobile information reference tool for farmers developed as an easy way to acquire and understand farming information. The service provided includes information on plant production (including information on seed varieties and various sources), high value crops as well as marketing (www.ikilimo.org).

KenCall farmers helpline: This is a profit oriented call center that provides real time agricultural advice, information and support to smallholder farmers by phone using voice and voice call-back to farmers (Payne et. al., 2010a). The service is provided by agricultural experts and primarily targets individual farmers in Kenya but will soon be accessible to agriculture extension workers in order to complement existing efforts of supporting and engaging the SHFs with varied but detailed information on how to improve agricultural production (growing, harvesting and rearing), planning (agricultural inputs and planting), negotiating and selling. Kencall has recently established a mobile telephone based helpline for farmers as an integrated online system of information collection, handling and dissemination. Farmers are provided with information on improved agricultural planning, production, inputs including seeds, processing, value addition, climate and marketing. For the usage of this service, farmers call the helpline with specific questions which are addressed by agricultural experts and subject matter specialists. This service primarily targets the smallholder farmers but also supplements the extension services with the relevant information (www.kencall.com).

Kilimo salama: This is an innovative mobile phone based scheme which allows farmers to insure seeds and inputs against climate change risks. The scheme operates through appointed dealers who sell seeds, fertilizers and chemicals to farmers with a small insurance premium. The farmer gets an insurance confirmation that is registered through a mobile phone SMS. The SMS contains the insurance details and the policy number. At the end of the season the farmer gets an SMS with information on whether there is a payout. In case of payout, the compensation is transferred to the farmer's mobile phone number via M-PESA, a popular and widely used money transfer system. The system is linked to weather stations that provide data on climatic conditions and the payouts are made when there are severe droughts and floods and there are high likelihoods that the farmers may have lost their seeds, chemicals and fertilizers (<https://kilimosalama.wordpress.com>)

M-Farm: This mobile platform provides an SMS service which allows farmers to buy agricultural inputs such as seeds, fertilizers and chemicals collectively or sell farm products directly to the market. Through the platform, groups of farmers can agree on a price and collectively sell directly to a buyer instead of selling through middlemen. This is done by farmers joining other farmers in their community through SMS subscription to the platform. In order to sell their produce, farmers send text messages giving information on the product, its weight and the asking price. M-Farm then matches local buyers and sellers on the basis of the prices they have submitted to the platform. The platform enables the 6,000 subscribed farmers to retain higher sales margins by circumventing value chain middle-men. M-Farm is a for-profit organization based in Kenya. The company started in 2010 and has grown to 7,000 users (<http://mfarm.co.ke>). The system features includes, market prices for 42 crops, group selling tool and SMS advertising, group buying tool for fertilizers and seeds and information dissemination, for example on international regulations.

National Farmers Information Service (NAFIS): This is a voice service which provides farmers with agricultural extension information accessed through mobile phones. NAFIS is updated through the Web, and a Text-to-Speech engine in both Kiswahili and English is used to create IVR automatically (www.nafis.go.ke).

Mkulima Farmer Information Service: This is a helpline and farmer information resource provided through mobile phones and the Web. It is a mobile IVR (Interactive Voice Response), service using USSD (Unstructured Supplementary Services Data) to guide farmers through a set of options when they are seeking information on a particular agricultural issue. This includes information on market prices for farm products, prices and sources of seeds and weather related information.

DrumNet: The basis of Drum Net's service is provision of an IT platform that targets agricultural suppliers in Kenya. The platform is compatible with mobile telephone networks, the internet as well as other wireless devices. This platform also enables Drum Net to provide such unique products as text messages, scouting, mapping of data and tailor made reporting. The incomes of Kenyan farmers who use the DrumNet app has risen by a third because of the service's comprehensive system of contracting, price negotiation and other value chain support. The service also enables rural residents and farmers to access extension services including inputs such as seeds and fertilizers, advice on agricultural production and information on marketing, technology, food security and nutrition (www.drumnet.net).

Variety information text messaging service: Through

this service provided by the Kenya Plant Health Inspection Services (KEPHIS), farmers are provided with information on planting and growing recommended crop varieties in their regions. This sms service provides farmers with information on recommended varieties of various crops that are suitable for their regions and ecological zones. The farmers send text messages specifying the name of the crop and the region and then get a reply with a recommendation on the right variety for their region (www.kephis.org).

The impacts of ICT-based agricultural advisory and extension services

Although the number of ICT-based initiatives providing agricultural extension and advisory services in Africa is growing, there is hardly any rigorous evidence-based impact assessment of use of ICTs in agriculture. According to the available literature, most of the studies have only assessed impact on prices and markets but even then the results are mixed. There are hardly any reports on the impact of ICT initiatives on cropping patterns, changes in crop production practices, availability and adoption of technology as well as productivity. Aker (2008) assessed the impact use of cell phones on grain trade in Niger. The author used a meta-dataset that combined subsets of data on transport costs, prices, rainfall and grain production. The study revealed that across markets, mobile telephones reduced grain price dispersion by a minimum of 6.5% and reduced the variation of intra-annual prices by 10%. The study also revealed that cell phones mainly affected market-level outcomes through a reduction in search costs since grain traders who used cell phones could cover a greater number of markets and sell in more markets. The results also suggested that cell phones led to increased consumer welfare during Niger's severe food crisis of 2005 and this may have averted a worse outcome. Likewise, Muto and Yamano (2009) found that in Uganda, the number of the farmers selling bananas increased in communities more than 20 miles away from district centers after the expansion of the mobile telephone coverage. This was based on data collected from 856 Ugandan households in 94 communities. The results imply that mobile phone coverage enhances the market participation of farmers who produce perishable crops and are located in remote areas.

In their studies, Verdier-Chouchane and Karagueuzian (2016) revealed that technologies with low infrastructure requirements and low costs such as the radio are the most used ICTs in the African continent compared to other traditional mass media such as newspaper, television and broadband fixed lines. For example, studies conducted in several sub-Saharan African countries (Ghana, Malawi, Mali, Mozambique, South Africa and Tanzania) revealed that rural radios that had innovative programs such as dramas and radio fora tailor

Table 1. Successful new ICT-based services in the agriculture sector in Africa.

Stage	ICT oriented activities	Status of application
Crop production stage	Enhancement of land tenure security for farmers by leverage GIS, Remote Sensing (RS) and satellite imagery technologies to (land registration, crop inventories)	Cameroon, Egypt, Ethiopia
	Payment tool for crop insurance and credit in the agriculture sector using mobile phones	Mozambique
	Build a virtual common information system platform (through mobile phone) linking all stakeholders in the agriculture sector, comprising a database containing farmers' information	Kenya (Kilimo salama, using M-PESA), Kenya (M-Kilimo), Kenya (NAFIS)
	Provision of information through mobile phones and mass media (radio, TV, newspapers) on crop cultivation, best agriculture management practices and market prices to enhance agriculture production and productivity in a sustainable way and increase farmers' income	Kenya, Mali, Tanzania, Ghana, Côte d'Ivoire (Agri VAS) Kenya, Malawi, Ghana, Tanzania, Zimbabwe, Mali (FVR) Kenya (KenCall, Mali Shambani, Shamba shape up, Seeds of Gold, iKilimo, Kilimo salama, Drum net)
	Use of mobile phones and internet based platforms in commodity exchange in dissemination of information on market prices and knowledge data on products as well as coordination and contract enforcement between buyers and sellers	Ghana (E-Soko) Ethiopia (Ethiopia Commodity Exchange) Kenya (Kenya Agricultural Commodity Exchange) Malawi (Malawi Agricultural Commodity Exchange) Ghana and Cote d'Ivoire (Cocoalink) Senegal (Manobi)
Post-harvest stage	Provide quality and traceability information on products through mobile phones to improve integration into global agriculture value chains	Nigeria (Trade Net Africa) Mozambique (SIMA) Uganda (Application Laboratory)

made for local communities were effective communication channels of agricultural messages (FRI, 2008a). Moreover, in Malawi, these studies found that farm radio messages led to farmer behavioral changes. These changes included reduction of overdependence on maize through crop diversification; engagement in soil improvement, on-farm tree planting, use of compost manure, crop rotation, small-scale irrigation, micro-enterprises, environmental conservation, home economics and nutrition (FRI, 2008a). The study also suggested that the use of farm radio is even more effective when complemented with new information and communication technologies (ICTs).

Another success story is "Talking Book" which is an ICT designed to provide information on agricultural technologies in local language to illiterate farmers using audio computer. A pilot study conducted in a rural village in Ghana in 2009 revealed that households using Talking Books on an intermittent basis grew 48% more food than other households (World Bank et al., 2011). A summary of successful ICT applications in agriculture is provided in

Table 1.

Factors influencing the use of ICTs in African agriculture

The application of ICTs in African agriculture is growing, especially the expansion of mobile telephones usage, though they have mainly been used to provide marketing information. However, this information alone may not necessarily lead to innovations and the desired increased productivity of smallholder agriculture if ICTs are not supported with such extension services as advice on improved agricultural practices, availability of agricultural technologies including seeds and other inputs as well as farmer education. The use of ICTs has several constraints compared to human-based extension service, which requires deployment of a large number of extension workers. These constraints can be summarized into three broad categories viz the rural setting; the policy environment; infrastructure and capacity constraints and

the nature of local communities including their inability to use the technology to access information for various agricultural activities.

The policy environment

The African continent as a whole continues to lag behind the rest of the world although the telecommunications sectors of some of the countries such as Ghana, Kenya, Nigeria and Senegal, are quite dynamic. This is primarily due to the high cost of services as revealed by a study that was conducted by Calandro et al. (2010) in 17 sub-Saharan African countries. This study argues that the achievement of affordable and universal access to the full range of ICTs has been undermined by poor policies which constrain market entry and the competitive allocation of available resources; weak institutional arrangements characterized by low technical capacities and competencies; and in some cases, regressive taxes on usage of ICTs. Furthermore, Gillwald (2010) argues that effective regulation is needed in order to enhance competition and open access regimes. Regulation of other factors such as spectrum, interconnection and tariffs are also required for stimulation of market growth, improvement of access to ICTs and lowering of their prices. This is exemplified in Cote d'Ivoire where many competitive markets with several players have experienced spectrum allocation problems as well as high cost of services due to retrogressive taxes on mobile communications despite having an open market with several operators as the case of Uganda. In some cases, the situation is made worse by expensive leased lines that are only provided by incumbent operators who are usually unregulated. This contributes to the high cost of conducting business and inhibits opportunities for ICT growth and development (Gillwald, 2010).

The rural setting, infrastructure and capacity constraints

Most of the rural areas are sparsely populated, making provision of such services as electricity, water, modern ICTs, infrastructure and public utilities difficult to deploy. Private firms are the primary ICT service providers and they invest their resources where they are likely to get good returns. They are therefore unlikely to invest in rural areas where returns on investments are minimal due to lack of essential services and infrastructure. For example, electricity which is an important requirement for provision of ICT services is quite limited in most of the rural areas in Africa and many countries still lack good GSM networks (Torero, 2014). In addition, rural people's incomes are normally lower than in urban areas and most rural households cannot afford modern ICTs such as computer, internet and mobile phones. The combined effect of all these constraints is a digital divide between

the rural and urban areas (Asenso-Okyere and Mekonnen, 2012). Moreover, unless there are strong incentives, ICT operators are generally unwilling to cover the rural areas because of the high cost of start-up, operating and programming in addition to the low capacity of the rural people to pay for the services (Souter et al., 2005).

The nature of local communities and inability to access information using technology

The level of education, income, social and cultural constraints influences the likelihood of an individual to have the necessary e-skills to use different technologies (Gillwald and Stork, 2010; Hafkin and Odame, 2002; Hafkin and Taggart, 2001). A study by Muto and Yamano (2009) in Uganda found that possession of mobile phones was directly related to the total value of assets and the level of education of household members. A scoping study conducted by Munyua (2008) on small-scale agriculture and ICTs in Africa found low usage patterns and anecdotal adoptions. The study also revealed that ICT initiatives were uncoordinated and scattered. It summarized the main challenges and factors that influence the use of ICTs as high cost of technologies, low ICT skills, inadequate infrastructure, poor and expensive connectivity, language barriers, inappropriate ICT policies, low bandwidth, inadequate and/or inappropriate credit facilities and systems. The study also identified other constraints including poor involvement of women and other disadvantaged groups, inadequate collaboration and awareness of existing ICT facilities and resources, inappropriate local content, weak institutions, a poor information sharing culture and low awareness of the role of ICTs in development at all levels.

A survey that was based on household and individual access and usage conducted across 17 African countries (Gillwald and Stork, 2010) revealed that the diffusion of ICTs such as mobile telephones, radio, internet and television was highly uneven. The diffusion concentrated in urban areas and left many rural areas almost untouched. The study also found out that income is a major constraint to the access and usage of these technologies. However, as the technologies become more complex, literacy and education increasingly become the main constraints. Further disaggregation of the data by gender revealed that women were more disadvantaged than men in the access and use of even the more prevalent forms of ICTs. The study also reported that such factors as education, income and social position played an important role in explaining and expanding ICT access and usage. It was also noted that the differences in access to ICTs and their usage were much less when men and women had similar academic and socio-economic backgrounds. However, women generally have less access to ICTs because of unequal

access to opportunities such as income and education, which seem to enhance ICT access and usage. This inequality increases as the services as well as technologies become more expensive and sophisticated, with their access and operation requiring higher income and education levels. Moreover, a study by GSMA (2010) revealed that women in low and or middle income countries are 21% less likely to own a mobile phone than men. This knowledge is unsettling for agricultural development in Africa where food production is primarily in women's domain and they need ICT related technology and market information in order to increase farming productivity and profitability. In their studies on agriculture, gender and ICTs in Africa, Hafkin and Odame (2002); Hafkin and Taggart (2001) identified several factors that hinder the use of telecenters and communication facilities by women. These include multiple roles and heavy workloads, which limit the time available for women to use telecenters; men's attitudes towards women's use of technology and to women visiting mixed-sex public facilities; opening of public facilities during evenings which exposes women to dangers; the lower levels of educational of women in comparison to men's and lack of disposable income to pay for services rendered in the centers, among others.

Conclusion

There is no doubt that the development of ICTs has facilitated the dissemination of knowledge and information and it is revolutionizing the use of technology in agricultural research, development and marketing. The wide range of ICT platforms have a great potential for increased use in dissemination of information on seeds, varieties and their sources as well as information on other agricultural inputs. However, there is need for better integration of information between the ICT service provides, agricultural research and development sector and private sector, especially private seed companies and agro-dealers.

It is also evident that rural incomes have increased with the use of ICTs in accessing knowledge and information. However, there are still challenges in accessing of ICTs and related platforms by a large number of the rural population who are engaged in agriculture. These challenges and constraints need to be addressed through public policy within the context of rural development in general and agricultural productivity in particular. It is worth noting that in Africa, the acquisition and usage of mobile phone has increased tremendously and when they are used in combination with other ICT platforms such as mass media, the impact on agriculture is likely to be very high. The expansion of access to these platforms could be increased through the reduction of costs of the devices and connectivity charges. A key strategy in the reduction of costs would be greater cooperation among African countries in rolling out ICT platforms, particularly

equipment and content.

CONFLICT OF INTERESTS

The authors has not declared any conflict of interests.

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