E-Agriculture Reviewed: Theories, Concepts and Trends

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Abstract — One of the foremost sectors that have shaped the socioeconomic development of most countries is agriculture. Over the years, the benefits accruing from the widespread adoption and use of information and communication technologies (ICTs) in agriculture includes increasing people’s knowledge and practice of agricultural processes and hence improving agricultural production and linkages to remunerative markets, food security, national economies amongst many other benefits. A field of activity related to the use of modern information and communication tools and technologies that increase agricultural productivity and make available information that is relevant to agricultural research, planning, extension, production, monitoring, marketing and trade is referred to as e-agriculture. In this paper, we present a methodical review of theories, concepts and trends of e-agriculture.

Keywords — Development, e-Agriculture, Globalization, Information and Communications Technology (ICT)

1 INTRODUCTION

Information and communication have always been essential ingredients of agriculture. Since time immemorial, farmers and other players in the agricultural practice have sought information from one another about market prices, planting strategies, available credit facilities, acquisition of land title and so on. Farmers in a settlement may have cultivated a particular crop for decades, but in the process of time, weather patterns, soil conditions change and epidemics of pests and diseases come and go. Updated information allows the farmers to cope with and even benefit from these changes (Mcnamara et al., 2011). Providing such knowledge can be challenging, however, because the highly localized nature of agriculture means that information must be tailored specifically to distinct conditions. Considering the above challenges, the advent of information and communication technology (ICT) is a timely response. ICT has introduced new methods of undertaking many activities by electronic means. Some examples include: e-commerce, e-banking, e-learning, e-government, e-democracy, e-voting, e-health and so on.

Corresponding to this is also the innovative porting of such applications to mobile devices such as smart phones and tablet devices; hence m-commerce, m-banking, m-learning, m-voting etc. These applications have tremendously changed the way we do many things. There is barely a community in our ‘global village’ that has not felt the effects of the ICT revolution. Most people are now regular users of mobile phones and keen consumers of ICTs. Also, governments in both the developed and developing worlds have responded by formulating ICT policies, putting in place regulatory frameworks and establishing institutional infrastructures. Their aim is to facilitate and bring order to these e-developments that are rapidly changing the world we live in. The World Summits on the Information Society (WSIS) held in Geneva in 2003 and Tunis 2005 aimed to bridge the global digital divide by expanding access to ICTs in developing countries (ICT Update, 2013). Agriculture was less of a focus than health and education during these events, but a call to develop ICT strategies for all sectors, including agriculture, was issued at these summits.

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Agriculture is a sector that holds great promise for pro-poor economic growth. Its role in economic development has long been recognized (Byerlee, De Janvry and Sadoulet, 2009). Agriculture also has significant linkage in its operations with other related sectors such as rural development, natural resource management, banking, insurance, media, governance, transportation and logistics management (FAO, 2016). In developing countries, the growth and development of the agricultural sector is even more crucial because it has particular and direct significance in attaining the first Millennium Development Goal (MDG), which is to eradicate extreme poverty and hunger, and the seventh MDG, which is to ensure environmental sustainability (Gitau et al., 2008).

However, the agriculture sector faces many challenges posed by climate change, loss of biodiversity, drought, desertification, increase in food prices and inefficient supply chains. The sector is increasingly becoming knowledge-intensive, and the availability of the right information, at the right time, in the right format, and through the right medium, influences and affects the livelihoods of many stakeholders involved in agriculture and related fields. 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 productivity, profitability, food security and employment opportunities substantially (FAO, 2016). The rest of the paper is organized into the following: Section two describes the “why, need and roles” of ICT in agriculture; Section three made a case for e-agriculture; Section four presents the global trends in e-agriculture both for the developed and developing world and Sections five summarized and concludes the subject matter of the paper.

2 ICT IN AGRICULTURAL DEVELOPMENT

2.1 THE NEED FOR ICT IN AGRICULTURAL VALUE CHAIN

In many local economies, the low availability of timely and needed information is skewed in favour of better informed individuals or organizations which often force disadvantaged farmers to sell their harvests below fair value. The uneven spread of infrastructure such as market, finance, administrative (government services) and physical (roads and so on) is equally problematic in developed and developing nations, leading to significant

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differences in the ability to leverage individual and regional strengths. Insufficient extension services and poor access to information widen the gap in the adoption of new technologies and can lead to lower long-term productivity (Miller, Saroja. and Linder, 2013).

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 TV, radio, newspapers, other farmers, government agricultural extension services, traders, input dealers, seed companies and relatives. 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 information and communications technology (ICT) solutions have emerged which are increasingly available, in even the remotest locations to help overcome these information gaps and improve business of agriculture proactively.

ICTs have been a major contributor to growth and socio-economic development 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 (Kelles-Viitanen, 2003; Lotter, 2007). But what are ICTs precisely? ICT is any device, tool, or application that permits the exchange or collection of data through interaction or transmission (Mcnamara et al., 2011). It is an umbrella term that includes all technologies for the communication of information. Even in developing countries, ICTs have gained traction. The increases in their affordability, accessibility, and adaptability have resulted in their use even within rural homesteads relying on agriculture (Mcnamara et al. 2011). The International Telecommunication Union (ITU) estimates that at the end of 2018, 51.2 per cent of the global population, or 3.9 billion people, will be using the Internet. Figure 1 depicts the global ICT developments from 2001 to 2018.

2.2 ICTs in Agriculture
ICT encompasses the use of existing technology: hardware, software and telecommunication options, including the Internet and telephony (mobile and landline) systems. ICT solutions for agriculture and value chains typically fall under a topic called information and communication technologies for development (ICT4D), which can also entail other types of development interventions in health and education, for example. 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 and incomes, and reduction in risks. Tools engaged in these interventions and their areas of usage may include:

i. Telephones – interactive voice response
ii. Computers and websites – agricultural information and markets
iii. Broadcasting – expertise sharing, advisory and community
iv. Satellite – weather, universal accessibility and remote sensing
v. Mobile – advisory sales, banking and networking
vi. Internet and broadband – knowledge sharing, social media, e-community, market platform, trading and so on.
vii. Sensor networks- real time information, better data quantity and quality, decision making
viii. Data storage and analysis- precision agriculture and actionable knowledge.

2.3 Roles of ICT in Agriculture
The adoption and application of ICT to agriculture can offer a wide range of solutions to many agricultural challenges. Over the years, the international donor community has rallied efforts toward bridging the digital divide between the developed world and the developing world to help maximize the impact of ICTs on the MDG outlined by the United Nations. The roles of ICT in agriculture include:

i. Agricultural extension and advisory service: ICTs bridge the gap between agricultural researchers, extension agents and farmers thereby enhancing agricultural production.

ii. Promote environmentally sustainable farming practices: ICTs improve access to climate-smart solutions as well as appropriate knowledge to use them.

![Global ICT Development (ITU, 2019)](fuoyejournal.com/journal/fig1.jpg)
iii. Disaster management and early warning system: ICTs provide actionable information to communities and governments on disaster prevention in real time, while also providing advice on risk-mitigation techniques.

iv. Enhanced market access: ICTs facilitate market access for inputs as well as product marketing and trade in a variety of ways.

v. Food safety and traceability: ICTs help deliver more efficient and reliable data to comply with international traceability standards.

vi. Financial inclusion, insurance and risk management: ICTs increase access to financial services for rural communities, helping to secure savings, find affordable insurance and tools to better manage risk.

vii. Capacity building and empowerment: ICTs widen the reach of local communities and provide newer business opportunities, thereby enhancing livelihoods.

viii. Regulatory and policy: ICTs assist with implementing regulatory policies, frameworks and ways to monitor progress.

3 The Case for E-Agriculture

3.1 Why E-Agriculture?

Agriculture accounts for the overwhelming majority of rural employment (Donovan, 2011) and it is the key contributor to the national gross domestic products (GDP) of many countries. In sub-Saharan Africa, agriculture still accounts for one-third of the gross domestic products (GDP) and three-quarters of employment in sub-Saharan Africa. Over 40 percent of the labor force in countries with per capita incomes in the US$ 400 to 1,800 range works in agriculture (World Bank, 2008). The importance of its growth to poverty alleviation and stimulation of economic growth and development in developing countries is pertinent. Available evidence reveals that sustainable poverty reduction can only be possible through economic growth and development strategies with agriculture being a key driver (Mcnamara et al., 2011).

Despite the key role agriculture plays in the economy of developing countries, it faces major challenges that have hindered the exploitation of its full potential to the economic contribution. Most farmers in these countries are smallholders (Lotter, 2007), and the challenges encountered by these farmers is multidimensional including: sub-divisions and small farm sizes, leading to diseconomies of scale and low productivity; inadequate knowledge and skills in modern farming techniques (poor agricultural practices) and optimum methods of management; inefficiencies in information delivery; information on best practices; storage difficulties and inadequate farmer experience with the marketing of produce; poor linkages between farmers, processors, markets, researchers and extension workers (Tiamiyu, Bankole and Agbonlahor, 2012; Munyua and Adera, 2009; Gichamba and Lukandu, 2012). Furthermore, it was notes by (Munyua and Adera, 2009) that farmers in developing countries often lack adequate information on inputs, markets, credit, improved technologies, commercial farming and other aspects of rural development, and that the use of ICT to deliver training and information is an essential ingredient for improving access to markets, production and productivity. Farmers need information on trending cropping techniques for pre-harvest, harvest and post-harvest activities in an integrated and comprehensive platform to assist farmers in making decision.

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 (Awuor et al., 2016).

3.2 What is E-Agriculture?

The Food and Agriculture Organization of the United Nations (FAO) proposes the following definition (FAO, 2005): “e-Agriculture” is an emerging field in the intersection of agricultural informatics, agricultural development and entrepreneurship, referring to agricultural services, technology dissemination, and information delivered or enhanced through the Internet and related technologies. More specifically, it involves the conceptualization, design, development, evaluation and application of new (innovative) ways to use existing or emerging information and communication technologies (ICTs).

E-Agriculture goes beyond technology, to promote the integration of technology with multimedia, knowledge and culture, with the aim of improving communication and learning processes between various actors in agriculture locally, regionally and worldwide. Facilitation, support of standards and norms, technical support, capacity building, education, and extension are all key components to e-Agriculture (FAO, 2005). A subset of e-agriculture is mobile agriculture (M-Agriculture). M-Agriculture refers to the provision of agricultural services and information, using mobile devices such as cell phones, Personal Digital Assistants (PDAs), tablets and other handheld communication or computing devices (Gichamba, and Lukandu, 2012). Mobile Agriculture supports actors along the agricultural value chain through the use of mobile technology.

Mobile technology covers a broad range of devices and the sub-categories include voice, data, network and connectivity technologies. The introduction of mobile technology and portable, wireless devices has led to the creation of innovative services and applications that are used within the agricultural value chain in developed and developing countries. In developed markets where mechanization is more advanced and the agricultural labour force is significantly smaller than that of many developing countries, mobile agriculture applications tend to be implemented further up the value chain, for example with processors or consumers. In developing countries where a large proportion of the workforce is employed in agriculture, mobile technology is more commonly used to deliver services for producers and traders.
3.3 Characteristics of E-Agriculture Benefits

Highlighted hereunder are characteristics of e-agriculture benefits (Ballantyne, Maru, and Porcari, 2010; FAO, 2016):

i. Transformation of processes: E-agriculture transforms the way actors in agricultural value chains collect, analyse, store and share agricultural information for their daily decision making purposes.

ii. Investments: E-agriculture development stimulates investment in ICT infrastructure and human capital.

iii. Efficient markets: E-agriculture leads to greater efficiencies in rural markets; lower transaction costs, less information asymmetries, improved market coordination and transparent rural markets. E-agriculture reduces wastage in various stages from the field-to-fork value chain. Around one-third of the food in the supply chain is either lost or wasted at the farm, during storage and distribution, or in households. By facilitating real-time information exchange, e-agriculture can improve supply chain efficiency which can significantly reduce such food waste.

iv. Improved vertical and horizontal linkages: E-agriculture results in the development of trust-based relationships between value chain actors. In conventional agriculture value chains, intermediaries add to reduced transparency and thus increasing price manipulation resulting in mistrust. E-agriculture can help in reducing the layers of intermediaries and can make transactions unbiased and transparent, thus improving the trust factor.

v. Facilitation of information sharing networks: E-agriculture facilitates the development of networks for agricultural information sharing and knowledge societies.

vi. Value-added Services: E-agriculture leads to the development of value-added services for rural farmers and other actors of the agricultural value chains.

vii. Reducing individual and institutional risk: E-agriculture can be leveraged to reduce uncertainty and enhance preparedness and response to climate change, disasters and other agricultural risks.

viii. Increased food and nutrition security and safety: E-agriculture can improve food management through efficient information flow, data gathering and analysis, traceability, transactions and supply chain management.

4 Global Trends in E-Agriculture

The digital divide between developing and developed countries is nowhere more evident than in agriculture. This is not only due to the different extent to which digital technologies have penetrated rural areas across the developed economies and the developing world, but also due to different farm structures. Farmers, their cooperatives, large, medium and small input suppliers, traders, processors and retailers use ICTs throughout the food value chain, from testing the soil in the farm to using 3D printers to process food. Applications of e-Agriculture in intensive agricultural systems in developed countries are gearing towards using sophisticated technologies to improve the quantity and quality of production, in order to maximize profits. This is the case in precision agriculture in which farmers are harnessing computer and satellite technologies to cut costs, improve yields and protect the environment; and e-commerce in which the marketing and sale of agricultural products is conducted over electronic networks such as the Internet and extranets.

In precision agriculture or site-specific farming, farmers are using ICTs and other technologies to obtain more precise information about agricultural resources which allow them to identify, analyze, and manage the spatial and temporal variability of soil and plants for optimum profitability, sustainability, and protection of the environment. Precision agriculture is described by (FAO, 2005) as: a system to manage farm resources better. Precision farming is an information technology based management system now possible because of several technologies currently available to agriculture. These include global positioning systems, geographic information systems, yield monitoring devices, soil, plant and pest sensors, remote sensing, and variable rate technologies for application of inputs. Precision agriculture is an advanced e-agriculture application. It makes use of five major components of technology (Rains and Thomas, 2000):

i. Geographical Information Systems (GIS) for analysis and management of spatial data and mapping;

ii. Remote Sensing (RS) for identification

iii. Global Positioning Systems (GPS) to locate and define spatial features or activities that contribute to the quality of site-specific practices;

iv. Variable Rate Technology (VRT) allowing targeted, site-specific input applications; and

v. Yield monitoring for recording crop productivity as an historical database for crop management.

On e-Commerce in agriculture, improved productions and high yields result in the need to look for profitable markets beyond local communities, and electronic markets are providing an opportunity to farmers to market and sell their produce to buyers at global level. On the other hand in many developing countries farmers’ access to information is improved through grass root level initiatives of using ICTs as well as distance education modalities to enhance knowledge base among service providers. In these parts of the world, absence of formally adopted e-agricultural strategies does not mean there is no activity in this field.

On the contrary, there is a rise in ICT-for-agriculture projects in developing countries, triggered by the ever-expanding mobile signal penetration that has already surpassed 90% in South Asia and is rapidly approaching 70% in Africa (ICT Update, 2013) 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 and so on. Furthermore, the advent of smart phones and tablets are extending the potential uses of mobile devices into a new generation of tools for obtaining personal agricultural extension and other professional advice. In most developing countries, e-agriculture and other similar initiatives are mostly isolated projects generally implemented on an ad-hoc
basis. They tend to lack a clear vision or approach that would ensure everybody in the value chain can actually access their services and help to rationalise budgets and resources (ICT Update, 2013).

Some of the trends and changes in e-Agriculture predictable in the future include (Ballantyne, et al., 2010):

i. Increasingly ‘ubiquitous’ connectivity along value chains – It is expected that all farmers will increasingly make use of a range of devices and platforms to access and share knowledge: from the web to phones, radio, video and text messaging. Most scientists will work in knowledge-rich environments; farming communities, probably using different devices, will be far more connected than at present. Multiple connectivity paths widen the potential reach of science.

ii. Increasingly ‘precise’ applications and tools – ICT and digital signatures or labels of various types will be used to track products from producer to consumer; to monitor local soil, weather and market conditions; to tailor data and information services to the demands of a specific audience or individuals. Applications will come in many shapes and sizes, to suit even the most specialized needs.

iii. Increasingly ‘accessible’ data and information – Vast quantities of public data and information held by institutions and individuals will become visible and re-usable at the click of a device. More intermediary skills and applications will be needed to help harvest, make sense of, and add value to these layers of data and information.

iv. Increasingly ‘diverse’ set of applications available across digital clouds – The digital ‘identities’ of scientists and their collaborators will give them access to a wide range of online tools and applications, accessible from any location and across different devices, enabling collaboration across boundaries as never before. Local firewalls and server configurations will not restrict global sharing.

v. Increasingly ‘inter-connected’ tools and knowledge bases – Different communities and their knowledge will be able to connect and share with each other, along the research cycle and across disciplines, including people with different engagement in science such as farmers, traders, politicians among others. A whole new breed of products and services will emerge to inter-connect and re-present diverse knowledge.

vi. Develop sustainable business and investment models through partnerships - public-private partnerships (PPP) are now considered essential to the long-term viability of most interventions that use ICT in agriculture. The public sector in developing countries particularly may need guidance in providing technological services; a lack of human and financial resources as well as the overwhelming needs of the agrarian population weakens its ability to provide widespread services of acceptable quality (World Bank, 2011). With private investment, public service provision can be more sustainable. Technical experts with experience in various subsectors; IT teams for technological maintenance, design, and troubleshooting; multi-level policy makers; and farmers and farmers’ organizations that can provide local know-how, are needed in one way or another.

5 CONCLUSION

Agriculture is an information intensive industry that is spatial in nature. To be successful, farmers must be generalists who are not only well versed in the latest farming technologies but also astute entrepreneurs who are technologically savvy. To cope with challenges posed by the globalization of agriculture, farmers have to produce quality product at par with world market at reasonable prices. Thus, farmers need to be well informed and well trained in the management of natural resources and production of agricultural commodities. E-agriculture can play an important role in addressing these challenges and uplifting the livelihood of smallholder farmers.

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