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Role of Information and Communication Technologies towards Sustainability Transitions in Agriculture and Food Systems

[1]Nwafor, S.C., [2]Agba, S.A., [3]Ugbem-Onah, C. and [4]Uwandu, Q.C.

[1]Farming Systems Research and Extension, National Root Crop Research Institute, Umudike, Nigeria
[2]Department of Sociology, University of Mkar, Benue State, Nigeria
[3]Department of Sociology, Benue State University, Benue State, Nigeria
[4]Ginger programme National Root Crop Research Institute, Umudike, Nigeria
Corresponding Author's email: solomonnwafor8@gmail.com

Abstract
Food sustainability transitions refer to transformation processes necessary to move towards sustainable food systems. Digitization is one of the most important ongoing transformation processes in global agriculture and food chains. The review paper explores the contribution of information and communication technologies (ICTs) to transition towards sustainability along the food chain (production, processing, distribution, consumption). It also reviewed the Challenges to ICT Use in the Food Chain. From the review, it was found that ICT has enormous roles to play in boasting food production and promoting equitable distribution and marketing of food produce. ICTs can contribute to agro-food sustainability transition by increasing resource productivity, reducing inefficiencies, decreasing management costs, and improving food chain coordination. Key challenges to effective utilization of ICT in promoting food security were identified to include lack of access to ICT tools, low literacy level, and inadequate capital among others.

Keywords: Information communication technology; Sustainability; Food security

Introduction

Information and communications technologies find application in various spheres of life and are used to perform a number of functions. According to Lashgarara *et al*. (2010), ICTs can be used for the purpose of enhancing rural decision power, extending rural markets, preserving the environment, increasing life quality and empowering the rural poor; and can be important in domains such as social development, research, education, extension, the management and control of organization, gender equality, hygiene, the environment, agriculture and nutrition. This is achieved through proper dissemination of information and monitoring of key signals necessary for efficient service delivery, including food production, hence food security. The necessary condition for obtaining food security is information because information is an important factor in the food system (Lashgarara, *ibid*). According to Clapp (2016) and De Schutter (2014), food insecurity results mainly from inequitable distribution of resources and information in the agriculture and food production system. In the opinion of Poppe (2016), to transform food value in Africa so that food security is enabled across the length and breadth of the continent; Information and Communication Technology (ICT) plays a pivotal role. A state of food crisis has remained a reality on the African continent because the processes of food production, distribution, and consumption have been predicated upon rudimentary procedures. In order to facilitate food sufficiency in present-day Africa, it is necessary to explore and utilize all benefits derivable from various ICT applications, especially at the level of policy planning.

In spite of the huge investment and annual budgetary allocation in the agricultural sector, and the impressive figures turned out by the National Bureau of Statistics, the number of people without access to adequate food and nutrition continue to rise annually, especially among sub-Saharan African countries. According to UN (2017), about 795 million people, or every ninth person, in the world is undernourished, with the majority living in developing countries and rural areas. Mbow *et al*. (2019) estimates that more than 1.02 billion people worldwide suffer from hunger with an estimated 830 million living in developing countries. In Nigeria, the Federal Ministry of Agriculture and Rural Development (FMARD) (2015) reported that an estimated 53 million Nigerians accounting for 30% of the population were hungry in 2010, while Oxfam (2017) reported that Nigeria ranks 110th in the global food index. While most

of the produce may never reach the consumers due to post harvest wastage occasioned by poor storage and handling facilities, most people lack knowledge of where to access the farm produce. This situation is largely as a result of poor information exchange within the agricultural food system. With about 68% mobile penetration and 28% internet penetration in Oluwatayo and Ojo (2019), ICT can play a key role in enhancing the food security situation in Nigeria.

Sustainability transitions is the ''long-term, multidimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard *et al.,* 2012.). In agriculture, the notion of sustainability transition applies to a shift from an agri-food system having as a main goal to increase productivity, to one built around the wider principles of sustainable agriculture. According to Spaargaren *et al*. (2013), food sustainability transitions refer to structural changes that give rise to new production and consumption modes and practices that are more sustainable. Sustainable agri-food system is a knowledge-intensive system that requires a new kind of knowledge. Knowledge and related information, skills, technologies, and attitudes will play a key role in sustainable agriculture. It is claimed that moving towards sustainability in agriculture and food systems call for innovative solutions and appropriate technologies such as ICT (Allahyari, 2009).

ICTs hold the potential to contribute to sustainability transitions in agriculture due to their disruptive potential. According to Wolfert (2015) and Poppe (2016), disruptive ICT trends include; mobile/cloud computing, Internet of Things, location-based monitoring (remote sensing, geo information, drones, etc.), social media and Big Data (web of data, linked open data). This paper is therefore designed to review the role of information and communication technologies towards sustainability transitions in agriculture and food systems. The paper is reviewed under the following sub heads: Contribution of Information And Communication Technologies (ICTs) To Transition Towards Sustainability Along The Food Chain, ICT in Food Production: Beyond Precision Agriculture, Challenges to ICT Use in the Food Chain Conclusions and recommendations are drawn from the review.

Contribution of Information and Communication Technologies (ICTs) To Transition towards Sustainability along the Food Chain

Information and communication technology finds relevance in all aspects of the food system and the agriculture production value chain. According to Zyl *et al*. (2012), cited in Oluwatayo and Ojo (2019), ICT finds application in three major aspects in the food production value chain. These are the pre-cultivation, crop cultivation and post-harvest stages. According to the authors, ICT can be deployed at the pre-cultivation stage in crop selection; land selection based on soil analysis, topography among others; calendar definition in planning of farm operations based on weather, activity and season; access to credit and access to input markets among others. At the second stage, ICT is used for land preparation and sowing, input management, water management and fertilization and pest management. The third stage involves marketing, transportation, packaging, food processing among others. All these are geared at enhancing productivity and promoting food security. Research by CTA (2017) shows that the benefits of using ICT in promoting households' food security are huge as ICT supports collaboration and cooperation among different stakeholders which promotes agriculture sustainability.

Specifically, ICT Promote information dissemination (Mensink and Vranken, 2017), has the potential for improving food security by enabling access to information and information dissemination on food production, market, input use, food processing and storage, food supply and consumption (Lashgarara *et al*., 2010). ICT also Promote effective linkage in the food system. The food system according to Mbow *et al* (2019) encompasses all the activities and actors in the production, transport, manufacturing, retailing, consumption, and waste of food, and their impacts on nutrition, health and well-being, and the environment. When there is effective information exchange and coordination within the system, productivity is enhanced, while wastage is reduced thus enhancing food security.

ICT is a major driver of technological advancement in agriculture, as evidenced in such fields as bioinformatics, farm automation and precision farming. Bioinformatics is the field of science that combines information technology and computer science with biology. Precision farming, or precision agriculture, is a technique that uses technology to collect and analyse data for the assessment of variations in soil or climate conditions, in order to guide the application of the right agricultural practices, in the right place, in the right way, at the right time. Farm automation involves the use of control systems, such as computers, to derive higher yields with more predictable results through farming processes that are more efficient, less labour intensive and less time-consuming. Empirical evidence suggests that, in the area of agricultural production, prices of inputs such as seeds, fertilizers and pesticides are the most frequently telecommunicated information. The telephone (mobile or fixed-line) is the communications technology most commonly used by farmers. Knowledge of variations in input prices will enable food producers to acquire inputs at the best possible prices and reduced cost of production (Olaniyi and Ismaila, 2016).

ICT helps to link the food production sector to the market at local, national, regional and international trade systems. According to Bello (2014) and Mensink and Vranken (2017), ICT provides a platform for market

networks that link sellers to buyers. ICT enhances the potential to search for information and increase the quantity and quality of information available, ultimately reducing uncertainty and enhancing market participation. A study by Olaniyi and Ismaila (2016) on ICT and households' food security in Nigeria confirmed that ICT improves household's food security by connecting rural agricultural households to markets and other agriculture stakeholders in the supply chain. In 2003, the World Summit on the Information Society addressed e-agriculture and highlighted as a priority the application of ICT in agricultural development (Kolshus *et al*., 2015). ICTs are increasingly used in modern agri-food sector and they have also been put forward as a means to enhance agrifood systems sustainability and to achieve food security. Svenfelt and Zapico (2016) reviewed the potential of ICT solutions for improved sustainability of agri-food systems by increasing efficiency, enhancing transparency and traceability, creating network between food chains actors, and improving food practices. The same authors argue that the way ICT is used in the solutions to improve sustainability in the food chain can be related to the Visible-Actionable-Sustainable ideas of Bonanni *et al*. (2010); ICTs make the food system and its impacts 'visible', to render it 'actionable' for making it more sustainable.

ICT in Food Production: Beyond Precision Agriculture

The role of ICTs in increasing system efficiency is a central theme in literature on ICT for sustainability. ICTs have been also used for a long time to improve resource efficiency and productivity in food systems (Thoni and Tjoa, 2017). In fact, ICT can decrease the use of agricultural inputs (fertilizers, pesticides, energy and water) as well as reducing environmental externalities. Many farms across the world are applying big data and data analytics to improve productivity of agricultural practices. They are being applied in a broad variety of farming activities such as equipment maintenance, fields mapping and other operational activities to optimize irrigation, sowing, etc. These solutions are becoming affordable but a key factor in their development will be margins on sale of agricultural produce. In fact, the key factor discouraging more widespread adoption of ICTs in agriculture is profitability i.e. demonstrating that uptake of ICTs improves farm profitability (FAO, 2011). In the developed world, ICTs serve as a basis for other technologies such as geographic information systems (GIS) and global positioning systems (GPS) in precision and site specific agriculture (IAASTD 2009).

A widely cited example of the use of ICT in agriculture in order to increase efficiency is that of precision agriculture. Precision agriculture is a modern farming model that consists in the utilization of sensors to optimize the use of pesticides, fertilizers and water (Mintert *et al*., 2016). It came into use in the 1980s as GPS became accessible by some farmers especially in developed countries, such as in the European Union. Modern precision farming makes use of GPS as well as sensors, GIS technology and advanced software. The methods of precision farming rely mainly upon a combination of satellite navigation and positioning technology, new sensor technologies, and the Internet of Things. Technology watch (2009) also reported that ICT is used in Monitoring and early warning. The systematic monitoring of world food supplies is a first and necessary step to address food security. This includes mapping agricultural production and food shortages and establishing comprehensive databases through remote sensing of agricultural and water resources by the use of high-resolution radiometers and moderate-resolution imaging spectrometers aboard aircraft and satellites; using computers, networks, databases and software to collect, analyse and share information that is relevant to food security. Deploying communication infrastructure (such as the Internet and mobile telephone) to send information and advice to individual farmers and consumers.

ICT in Food Processing, Distribution and Consumption

While ICT innovation was mainly used in the last decades to improve agriculture productivity and efficiency, and they continue to be so, there is also a growing interest in ICT solutions for post-harvest, transport and storage stages of the agricultural value chain. ICTs can benefit transport systems at various levels in terms of cost reductions and efficiency increases. In some situations, they can also help to overcome some problems in transport infrastructure. The cost of food transportation, and eventually also that of food processing, can be reduced if the limited transportation facilities are used more efficiently (Nwafor *et al*., 2019). ICTs and sensor-based applications can be used to enable evaluation of the current situation in transport logistics; they can be used to optimize transportation and logistics processes by monitoring different parameters such as fuel use, speed and position, thus making the supply chain more efficient (Lehmann *et al*., 2012). Some applications, such as Sourcemap, allow visualizing supply chain information in relation to environmental impact. Sourcemap has been effectively used for improving the efficiency and sustainability of ingredient sourcing, by reducing distance between ingredient production sites and processing plants thus reducing transportation costs (Bonanni, 2010).

ICT is used for facilitating retailing ways, e-commerce, online ordering and deliveries, can potentially substitute traditional retail and allow a better coordination of food distribution. While most scholars agree that transportation costs can be reduced with use of ICT purchasing systems, there are divergences with regard to the effect on environmental impact of distribution. Siikavirta *et al* (2000) showed that e-grocery home delivery could reduce greenhouse gas emissions (GHG) in Finland. Williams and Tagami (2001) found that in dense urban areas, traditional retail had lower environmental impact than e-commerce. In fact, it

seems that the environmental impact of e-commerce depends on the efficiency of transportation. Therefore, business-to-consumer and business-to-business transportation need to be efficient if e-shopping is to improve environmental sustainability.

Challenges to ICT Use in the Food Chain

There are many challenges that should be addressed in order to increase the use of ICTs in agriculture and food systems. Wolfert *et al*. (2014) identified some bottlenecks of development of ICTs in agriculture such as small-scaled and isolated software development, regional focus and cultural differences, difficult or impossible inter-operability between various systems in the supply chain or at farm level, complicated handling and integration of large amounts of data (e.g. data from agricultural equipment). Schrijver *et al*. (2012) pointed out that the use of ICTs, especially in the context of precision agriculture, will trigger societal changes, especially in rural areas. In spite of the enormous benefits and prospects of ICT in promoting food security, this has not been fully realized in sub-Saharan Africa in general and Nigeria in particular, due to a number of challenges. There is generally low level of ICT literacy among the Nigerian populace. According to Bello and Aderbigbe (2014); Olaniyi and Ismaila (2016), the rural population has less skills and knowledge in utilizing ICT compared to urban population. Since most of the food production activities take place in the rural areas, low ICT literacy will affect information dissemination and agricultural productivity with adverse effect on food security. Danaan (2006) noted that high level of illiteracy and lack of technical know-how among farming population accounts for sub-optimal utilization of ICT in fostering food security. According to the Technical Center for Agriculture (CTA, 2004), illiteracy hampers versatility in the use of ICTs making the number of farmers who are hooked to these technologies few and far below expectation. This, according to Mboho (2007), limits the ability of farming households in using the modern technologies effectively to promote food security dimensions. According to Mensink and Vranken (2017), the role of ICT in food value chain is hampered by high cost, low connectivity, limited capacity and content especially in rural areas. Showole and Hashim (2014) identified poor connectivity, lack of relevant content, lack of ICT infrastructure and skills, high cost, inefficient and poor quality service, as the major impediments for effective utilization of ICT in the food production value chain. Manu (2002) identified low level of ICT readiness of not only the research and extension organization but indeed of the developing countries themselves as challenges. Other challenges include; high level rural poverty, high level illiteracy of farmers and computer researchers and extension. Al-Alwani (2005); Albirini (2006); Ghavifekridentified limited accessibility and network connection, limited technical support on ICT, and lack of effective training, among others as challenges.

Conclusion

Food systems need a radical transformation to become sustainable. ICTs can contribute to this food sustainability transition by providing new ways of visualizing and measuring impacts, communicating necessary changes and connecting food chain actors. New ICT technologies and services help food operators deliver greater efficiency in resource use. Therefore, digital technologies hold potential of reducing inefficiencies within food supply chains. They are also critical in helping to bring about the changes in food consumption patterns and practices needed to move towards sustainability in the food chain. In order to maximize the benefits of ICTs in food chains, also in developing countries, it is necessary to develop applications and services that are user-friendly, relevant, localized and affordable. Actions in policy, science and innovation are necessary to encourage the development of affordable, locally appropriate, and sustainable ICT infrastructure, applications, services and tools for agriculture and the rural economy. ICTs can have both positive and negative impacts related to sustainability in agro-food systems. The capacities of ICTs on food security are related to improving communication between research systems, farmers and extension, improving accessibility to information regarding inputs, introducing technologies, providing more rapid accessibility to high quality information, ensuring information about the appropriate times and places for optimized sales of agricultural products, increasing agricultural products and decreasing agricultural product losses (Temu and Msuya, 2004). This review thus recommend among others that ICT infrastructure such as electricity, internet facilities and computers should be developed in both rural and urban areas to facilitate effective information dissemination. Training programmes should be organized by relevant government ministries and agencies, non-governmental organizations etc to enhance the capacity of stakeholders in the utilization of ICT.

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