Sustainable food systems and agriculture: the role of information and communication technologies

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Abstract. Food security refers to the transformation processes needed to move towards sustainable food systems. Digitalization is one of the most important transformational processes in world agriculture and food production and sale systems. The paper considers the contribution of information and communication technologies (ICT) to the transition to sustainable development within the food chain (production, processing, distribution, consumption). Particular attention is paid to precision agriculture as a food production model that integrates many ICTs. ICTs can facilitate the transition to agri-food sustainability by increasing productivity and resource efficiency, reducing management costs and improving coordination in the food chain. The paper also discusses some disadvantages of ICT and factors limiting their use in agriculture.

1. Introduction

Information and communication technology (ICT) is an area of activity and research that includes technologies such as desktop and laptop computers, software, external devices and Internet connections designed to perform information processing and communication functions. Another definition of ICT is contained in UNESCO documents, which say that ICT is a combination of information technology with other related technologies, in particular, with communication technologies. Thus, ICTs use the latest technology to process and transmit information. According to the World Bank, information and communication technologies consist of hardware, software, networks and information tools for collecting, storing, processing, transmitting and presenting information. They include radio, television, telephones, computers, Internet technologies and databases.

Interaction, information exchange, transactions, knowledge transfer are fundamental in almost all aspects of agriculture. Therefore, the digitalization of agriculture and food systems occupies an important place in the political programs of all countries. For example, the G20 Agriculture Ministers' Action Plan has highlighted an entire chapter on ICT in agriculture. In this document, the Ministers reaffirmed their commitment to promoting ICT innovation in order to increase the efficiency and sustainability of the agricultural sector [1].

The food system is closely linked to many issues, such as climate change, biodiversity loss, water and food shortages. In this regard, there are more and more calls for a transition to sustainability in food systems [2-3]. Ensuring sustainability of development under conditions of rational nature...
Management can be defined as long-term, multidimensional, and fundamental transformation processes through which established socio-technical systems transfer to more sustainable methods of production and consumption [4]. In agriculture, the concept of sustainable development implies a transition from an agri-food system, the main purpose of which is to increase productivity, to a system built on broader principles of sustainable agriculture [5].

A sustainable agri-food system is a knowledge-based system that requires a new kind of knowledge. Knowledge and related information, skills, technologies and approaches will play a key role in sustainable agriculture. It is argued that the transition to sustainable agriculture and food systems requires innovative solutions and appropriate technologies, such as ICT [6-7]. ICT breakthrough trends include mobile/cloud computing, the Internet of things, location-based monitoring (remote sensing, geo-information, drones, etc.), social media and big data (data network, concatenated open data).

The first use of ICT in agriculture dates back to the 1960s. In 2003, the World Summit on the Information Society addressed the issue of e-agriculture and highlighted the application of ICT in agricultural development as a priority [8]. ICTs are increasingly used in the modern agri-food sector, which also emphasizes their role as a means of enhancing the sustainability of agri-food systems and achieving food security. The potential of ICT solutions to increase the sustainability of agri-food systems lies in increasing efficiency, transparency and traceability, creating a network of interaction between participants in food chains and improving food production technologies.

This study provides an analysis of how ICTs have contributed to sustainability in agriculture and food systems. The paper analyzes the benefits of ICT for sustainable development in agriculture/production, processing, distribution and consumption of food, as well as their impact on the integration and coordination of the food chain. In addition, the existing problems and disadvantages associated with the increasing use of ICT in agri-food systems have been identified.

2. ICT in food production

ICT can help reduce the use of agricultural resources (fertilizers, pesticides, energy and water), as well as reduce external environmental externalities [9].

Many farmers around the world use big data and data analysis to increase the productivity of agricultural practices. Multinational corporations such as Dow AgroSciences, Deere Co and Monsanto are actively investing in agroinformation systems. These systems are used for a wide variety of agricultural work, such as equipment maintenance, field mapping and other operational activities aimed at optimizing irrigation, sowing, etc. These technical solutions are becoming available, but the key to their development will be the profitability of agricultural sales. In fact, the main factor hindering the wider adoption of ICT in agriculture is the successful demonstration of how the introduction of ICT increases the profitability of farms. There are many examples of agricultural data exchange platforms (Fieldscripts, FarmBusinessNetwork, FarmMobile, Agriplace, FIspace) [10]. In developed countries, ICTs serve as the basis for the application of other technologies, such as geographical information systems (GIS) and global positioning systems (GPS) in the field of precision farming and localized agriculture.

A widespread example of the use of ICT in agriculture in order to increase efficiency is precision farming [10-12]. Precision farming is a modern agricultural model that uses sensors to optimize the use of pesticides, fertilizers and water. This approach began to be applied in the 1980s, when some farmers, especially in developed countries, gained access to GPS (table 1). Modern precision farming uses GPS, as well as sensors, GIS technology and modern software. Precision farming methods rely mainly on a combination of satellite navigation and positioning technology, new sensor technologies and the Internet of things [13].

In variable speed technologies, data from different sensors allow adapting the input values to the current needs of crops and the differences between parts of the same field, rather than apply the same amount of resources to all areas. ICT-based decision support systems help farmers maximize production efficiency while minimizing production costs and the environmental impact of their
activities [14]. In general, accurate agricultural technologies can reduce greenhouse gas emissions, thereby mitigating climate change by increasing the ability of soils to bind carbon.

Precision farming technologies are present at all stages of crop production and are increasingly used in livestock farming to increase both economic efficiency and overall sustainability of operations. Precision farming technologies are currently being developed with an expected annual growth rate of 12% until 2020. The most promising markets are the European Union and the United States.

Precision farming can actively contribute to food security and support the environmental sustainability of agriculture. In recent decades, more and more attention has been paid to precision agriculture in Russia, as evidenced by the emphasis on these technologies from agricultural consulting services. However, precision farming technologies are still not available to many farmers in developing countries.

ICTs can improve rural livelihoods and empower smallholder farmers in developing countries by expanding access to agricultural and market information. The use of ICTs also contributes to the development of social justice and equity by empowering less protected groups (for example, women, the elderly, youth) in rural communities of developing countries [15].

Agricultural innovation is the timely access and use of available information to respond to opportunities and threats. In developing countries, ICTs are widely used by outreach and advisory organizations to provide farmers with information (for example, weather forecasts, crop and livestock diseases, market prices for resources) through short message service (SMS), web portals and call centers [16 -17]. Thanks to ICT, several innovative application and service models have been developed, such as FAO's research and dissemination systems (VERCON). ICT, especially mobile telephony, allows farmers to access financial services (for example, savings, credit, insurance, means of payment and money transfers) at low prices.

Although in recent decades ICT innovations have been associated mainly with increasing agricultural productivity and efficiency, there is also a growing interest in solutions at the stages of post-harvest processing, transportation and storage of agricultural products.

ICTs can benefit transport systems at various levels in terms of cost reduction and efficiency gains. The cost of transporting food and its processing can be reduced by more efficient use of limited transportation capabilities. ICT and sensory applications can be used to assess the current situation in transport logistics; they can be used to optimize transport and logistics processes by monitoring various parameters, such as fuel consumption, speed and position, which makes the supply chain more efficient. Some applications, such as Sourcemap, allow visualizing information on the environmental impact of the supply chain. Sourcemap is effectively used to increase the efficiency and sustainability of ingredient searches by reducing the distance between manufacturers and processing plants, which reduces transportation costs.

3. Opportunities and existing problems in the use of ICT in the system of production and sale of food products

ICTs have an impact on the organization, integration and coordination of food chains at local, regional and global levels. Modern ICTs expand farmers' access to information, providing them with many opportunities to buy used resources and sell products [18-19]. Strengthening the position of farmers (including small ones) in the market has far-reaching consequences in terms of the transition to sustainable development of food systems.

The sustainability of the food system can be greatly enhanced thanks to the potential of the Internet of Things (IoT) technology, which allows visualizing, tracking, controlling and, thus, optimizing processes in the food chain using self-adaptive, autonomous and intelligent systems. In addition, Internet technologies and ICTs have contributed to the development of new concepts of agri-food chains (for example, food networks, urban agriculture) linking regional producers and consumers [6]. In fact, ICTs play an important role in improving communication and coordination between the various parts of the supply chain, especially between producers and consumers.
ICT and information systems can be used to increase traceability of agri-food products and transparency of food chains. They facilitate management and increase the accuracy of information. Tracking systems have become important for quality and food safety.

In addition, some ICT applications have allowed the creation of food communities that address the problem of surplus products in order to avoid the creation of food waste, which is the waste of resources such as fresh water, arable land and resources (for example, fertilizers) [20]. This applies to food banks that exist in many countries [21].

Despite the well-documented positive consequences in terms of the sustainability of the food chain, the use of ICTs can also lead to some negative consequences (Table 1). ICT solutions developed in isolation from the realities and practices of producers and consumers are more likely to complicate rather than expand the opportunities for transition to sustainable development in the food system. Created ICT solutions should take into account production practices, communication in the food chain, consumer behavior [9]. Data collection is one of the key challenges associated with the use of digital technology in the food chain. For example, large companies, thanks to feedback loops on the equipment they sell, can collect a large amount of farm data, which is of great concern to farmers. Agrochemical multinational corporations with data on a large number of farms in different countries can use them to create a monopoly in the market for major crops, which will have consequences in terms of food security and livelihoods of farmers in developing countries.

Table 1. The impact of ICTs on the sustainability of agri-food chains.

| Sustainability aspect | Expected positive results                                                                 | Potential negative impact                                      |
|-----------------------|------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| Environmental         | Improving the efficiency of using natural resources (water, land, energy) and man-made resources (fertilizers, pesticides) Reducing the impact and negative external environmental effects of agriculture and agri-food processing (e.g. water pollution), reducing the contribution of the agricultural sector to greenhouse gas emissions Reduce food loss and waste | E-waste generation and disposal of ICT equipment in rural areas |
| Economic              | Reduction of production, transportation and distribution costs Increase productivity and profitability Reducing transaction costs in the system of production and sale of food products Connecting small producers to markets | Initial increase in production costs through investment Increased risk of dominance of multinational companies in the agri-food market |
| Social                | Improving food supply chain transparency Facilitating access to information for all participants in the food production and sale system Enhanced traceability/food safety Strengthen connections between food chain actors Empowering small farmers Improving agribusiness efficiency | Separation of producers and consumers due to the development of virtual relationships Growing reliance on technology, the increasing impact of globalization The risk of increasing isolation of small and non-computer literate manufacturers |

Currently, there are still quite a lot of problems in the field of ICT application in agriculture and the food system. The analysis made it possible to identify a number of bottlenecks in the development of ICT in agriculture, such as small-scale and isolated software development, regional focus and cultural differences, difficult or impossible compatibility between different systems in the supply chain or at the farm level, complex processing and integration of large volumes of data (e.g. data on agricultural equipment). The use of ICTs, especially in the context of precision farming, will lead to social change,
especially in rural areas. In addition, mastering precision farming technologies can be a problem for farmers who may need to learn new skills.

FAO identified seven critical success factors and challenges in making ICT accessible to farmers and rural communities:

– Content (adaptation of the content to the needs of farmers in terms of format and relevance);
– Development of ability (the ability to effectively use technology and information at the individual, organizational and institutional levels);
– Gender issue and diversity (difficult and limited access for women, elderly and poor farmers, and people living in remote areas);
– Access and participation (gender and rural-urban digital divide persists);
– Partnerships (small and mostly inefficient public-private partnerships);
– Technologies (the task of determining the correct combination of technologies that meets local conditions);
– Economic, social and environmental sustainability (difficult expansion of pilot projects and ICT initiatives).

4. Conclusions

Food systems need a radical transformation to become sustainable. ICTs can facilitate this transition to food sustainability by providing new ways to visualize and measure impact, reporting about needed changes and connecting food chain actors. New ICT technologies and services help food operators increase resource efficiency. Therefore, digital technology has the potential to reduce inefficiencies in food supply chains. They also play a critical role in helping to change the patterns and practices of food consumption needed to ensure the food chain sustainability. To maximize the benefits of ICT in food chains, including in developing countries, it is necessary to develop user-friendly, relevant, localized and accessible applications and services. Policy, science and innovation measures are needed to promote the development of affordable, locally relevant and sustainable ICT infrastructure, applications, services, and tools for agriculture and rural economies.

ICTs can have both positive and negative effects on the sustainability of agri-food systems. In fact, the introduction of ICTs leads to far-reaching changes affecting individuals, society and the environment. Agriculture changes significantly with the increase in the number of devices and the increase in their connectivity. Besides the benefits of digital innovation, there are also problems and threats that need to be addressed. In this regard, it is necessary to conduct additional research on the impact of decisions and applied ICT programs on the sustainability of agriculture and food systems. Such a study should be based on a holistic approach and take into account the complexity of the food system, as well as the interaction between its various components and actors. However, it is also important to first determine what a sustainable food system should look like in each specific context, and then see how ICTs can contribute to sustainability.

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