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Review

Digitalization in Agricultural Sector: Agriculture 4.0 for Sustainable Agriculture

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Abstract: Sustainable and resilient systems within the food industry play a key role in global growth and development. In recent years, negative effects such as drought caused by climate change, destructive natural disasters, and destruction of biodiversity and natural resource erosion, agricultural migration, aging agricultural population, and global epidemics have deepened the environmental concerns. Apart from the negative effects on the food supply, pressure on the demand side is created by the growing population, which makes it necessary to create a new agrarian policy. Technological development has affected agriculture and agricultural production systems. One of the most prominent approaches is the integration of a new generation of digital technologies into the agricultural system, ensuring maximum benefit from information and data. Digitalization and the use of digital data have fundamentally transformed the agro-food system. The aim of this paper is present in a systematic view the agricultural digital transformation in the Agriculture 4.0, in the framework of sustainable development of agriculture. The aforementioned imposes sustainable agriculture by adequate agricultural policy instruments.

Keywords: Agriculture 4.0; agricultural sector; digitalization; sustainability; transition.

1. Introduction

Innovations in the agricultural sector represent a powerful catalyst in alleviating extreme poverty and in stimulating prosperity and development of society. According to the predictions of the World Bank, the global population will reach 9.7 billion inhabitants by 2050, which implies a double demand for food [1]. The significant growth in the income of economically weak countries speaks in favor of the mentioned fact, since these economies have achieved two to three times higher industrial growth rates.

In the Republic of Serbia, according to the data of the Republic Institute of Statistics, the sector of agriculture, forestry and fishing participated in the formation of the gross domestic product in 2022 by 6.3% and has realized a decrease in gross added value of -6.3% compared to 2021 [2]. The agricultural sector is struggling with a number of challenges, such as the lack of basic market information for agricultural products and inputs, together with the decline in real income of the population, which hinders the potential of the sector. The importance of the agricultural sector for the Serbian economy is great, because Serbian agriculture is relatively small in the European framework, but agriculture as a sector is of great importance on the path of the Republic of Serbia towards EU accession [3,4].

Digitalization is essential to promote the transformation of agriculture to improve the well-being of farmers in developing countries. Digitalization provides farmers with relevant, timely information and services, thereby facilitating farming, leading to increased profitability and sustainable businesses. As a result, digitalization is emerging as a powerful force for increasing rural income, food security and national economic growth by enabling informed decision-making and connecting small producers to lucrative markets [5]. The advancement of the digital transformation attracts non-traditional subjects in agricultural value creation chains, promotes reliable research and policy formulation, and improves the efficiency of agricultural supply networks. The aforementioned convergence of technology and agriculture, also known as e-agriculture or digitalization of agriculture, is an emerging sector driving agriculture and rural development [6].

The aim of this paper is present in a systematic view the agricultural digital transformation in the Agriculture 4.0 in the framework of the sustainable development of agriculture. There is no single methodology that can be used when measuring the degree of digitalization in agriculture with proven validity and reliability. The lack of knowledge makes the measurement of the level of digitalization in agriculture the focus of this paper. For this reason, the goal of this work is to present the concept of the digital technologies in agricultural sector.

2. Digitalization in agriculture

Although the term “digitalization” is widely used, it is still open to different definitions due to its dynamic character and the multiple aspects from which it can be viewed. According to Del Río Castro et al. [7] digitalization refers to the process by which digital technologies provide new opportunities for the value creation. Digitalization represents the application of the digital technologies in various sectors of the economy, as well as areas of social life with the aim of converting “analog” signals into fragments of information available in the form of digital language [8]. However, digitalization is not exclusively a sectoral activity with clearly established boundaries, because digital innovations from different sectors of the economy and society are converging and thus transforming industries and actors participating in them. What the various definitions of "digitalization" have in common is the transformational potential of digital technologies. Digitalization is an instrument for solving sustainability problems and there are several indicators according to which the approach to sustainability will play a key role in the development of the digital era [9].

Gong and Ribiere [10] define digital transformation as a process of change enabled by digital technology that brings radical innovation and has the potential to positively change social units (individuals, organizations, networks, communities or even society as a whole) by creating opportunities to create new value. However, the fact that uncertainty and possible harmful effects accompany digitalization should also be taken into account.

Digitalization in agriculture is the process of using data-rich software, hardware and services to increase productivity and efficiency while reducing costs, required work effort and environmental protection and reducing agricultural externalities [11,12]. The consequence of digitalization in agriculture is the rise of new forms of technology and data-driven agriculture, which authors often call digital agriculture [13,14], smart agriculture [15,16] or Agriculture 4.0 [17,18].

Digital agriculture carries certain risks and open questions. Historically, digitalization represents an evolutionary step in a series of very significant stages of technological progress in agriculture: from the mechanized industrialization of agricultural production [19] followed by the development of industry and the transition from labor-intensive production with low productivity Agriculture 1, to technology-intensive production Agriculture 2, to the launch of the “green revolution” Agriculture 3, in the 1950s (the possibilities of agrochemistry and agrogenetic engineering including chemical fertilizers, agrochemicals, vaccines and genetic modification). In the 1950s, agricultural mechanization was understood as agricultural technology. In the 1990s, the use of GPS signals began, and agriculture received the name "Precision Agriculture". Thanks to GPS technology, manual guidance, variable rate systems applied to harvesting machines and special monitoring of the fertilization process are the main technologies applied in this period. With precision breeding

methods, monitoring and solutions specific to each plot of land or each animal in the herd are offered, and the process is more manageable and production costs are effectively reduced.

After 2010, developing sensor technologies, high-bandwidth mobile communications and big data analytics are becoming pioneer implementations in agricultural applications. The Internet of Things (IoT) is one of the most important technologies of Industry 4.0 and the main component of agricultural applications within Agriculture 4.0. Raw data collected by various sensors is transferred to the cloud. With sensor technology, information such as type of fertilizer to be used, soil condition, irrigation and amount of minerals, estimated harvest time and weather conditions helping farmers to make optimal decisions for production, thus management is optimized and productivity is ensured [20].

3. Agriculture 4.0

Digital agriculture, encompassing digital and geospatial technologies to monitor, assess and manage soil, climatic and genetic resources, illustrates how to meet new challenges „so as to balance the economic, environmental and social dimensions of sustainable food production" [21] (p. 254). The prospect of digitalization encompasses the question how we can facilitate the shift to a new way of working in agricultural science [22].

The concept of Agriculture 4.0 that integrates the use of information-communication technologies presents a direction in which the domestic agriculture sector should focus, that can also contribute to achieving competitiveness on the globalized market [23]. The issues such as food availability, food safety, food recall, as well as food waste, provide insight into future food system scenario [24]. Afiza and Soon [25] claimed that the product recalls and other food-safety related risks are becoming more pronounced in the agro-food industry and all parties involved should consider adopting smart technologies as a method to prevent unfavourable incidents such as the spread of a virus, infected meat and meat products, and food poisoning. Consumers attach importance to the quality of the food products and that the information provided on the packaging is important to them [26].

Agriculture 4.0 refers to the use of internet of things (IoT), big data, artificial intelligence and robotics. The growth of global demand for quality and safe food products encourages producers and companies to improve and digitalize the production, transport and promotion of their products. Effective information management, i.e. a good flow of information between producers/sellers and consumers/buyers on the other hand, should contribute to adding value to products and better relations between suppliers and buyers, as the volume, speed and quality of information exchange increases. New digital applications for planning and management of the agricultural production can generate significantly more information. Integrated ICT technology is gaining a comparative advantage and developing many businesses based on integrated ICT technology. Agriculture 4.0 has a focus on precision agriculture, the internet of things (IoT) and the use of big data to derive greater business efficiencies. Agriculture 4.0 can avoid unnecessary waste by calculating the exact water requirements of the crop or timely detecting the onset of certain plant diseases. It uses artificial intelligence to accumulate big data, estimate the current situations and offer real-time solutions. On the farm, for example, the artificial intelligence can assist the farmers in improving the harvest quality, by detecting potential diseases and pests in plants, as to determine which herbicides should be used.

4. Implications of a transition to a digital agriculture

Digitalization and the use of digital data have fundamentally transformed the agro-food system, thus leading to radical changes in the entire chain of agricultural production. This transformation process is currently facing a new stage of digitalization and technological advancement, in which the further development of information technologies such as the Internet of Things (IoT), cloud computing, big data analytics, and artificial intelligence (AI) accelerates the digitalization process [27,28]. Digital data is becoming a new type of business resource, which, together with algorithms, permeates all domains of human activity [29]. Klerkx and Rose [30] believe that the digital connection

of almost all processes of agricultural production and the value chain (IoT) represent changes in business conditions, which according to Walter et al. [31] constitutes the next "technical revolution" in agriculture.

The next phase of digitalization in agriculture leads not only to new opportunities but also causes certain consequences. The socio-technical transitions of digital agriculture and smart farming bring numerous benefits and new potentials [32]. According to Jakku et al. [33], digitalization has advanced the agricultural production chain offering and enabled better economic potential due to increased efficiency, better quality decision-making based on timely information, increased productivity and profitability. This transition promotes and improves resource efficiency and has a positive impact on climate change, biodiversity, animal welfare, improving transparency and traceability of food production for consumers. Digitalization increases the possibilities of more sustainable and ecologically oriented agricultural practices, since it uses more precise application of nutrients and/or pesticides that are adapted to the conditions of plants, soil and other environmental factors, reducing wastewater and the greenhouse effect [34]. In addition, the possibilities of monitoring and improving the quality of information provided by digital technologies are improved, resulting in new options for the design and implementation of agricultural policies [35]. Digitalization offers opportunities to mitigate global challenges facing the food industry, such as climate change, land degradation and a growing world population.

Technological progress has led to drastic increases in yields and improved efficiency, but it has also had undesired effects, especially in terms of environmental consequences [36]. The digital transformation in agriculture has led to significant socio-technological development, but certain risks are associated with it, such as: risks of growing inequality that arises as a consequence of unequal access to new technologies due to different financial opportunities of agricultural producers, and thus changes in power and concentration in favour of several global agricultural suppliers and technology companies.

As in other industrial sectors, there are growing concerns about the risk of data misuse and the asymmetry of the increase in the number of data: agricultural producers disclose personal data about the management of the economic company, but are very poorly informed how this data is stored and used and whether they have any control over it. The implementation of digitalization also involves more complex technical systems, which makes them more fragile to internal system failures [37] and can attract malicious actors who want to threaten the cyber security of digital systems. Digitalization can affect rural employment patterns, for example, through job cuts or new employment profiles [38].

Agricultural digitalization can contribute to food safety, risk prevention and smart decision-making in the food supply chain. The development of the new models of agricultural digitalization reveals opportunities and needs to generate significantly more information thus created increases food safety, enables compliance with food safety regulations and traceability, food labelling, presence of allergens, i.e. monitoring of all agents and factors to which the food industry and companies involved in the supply chain are exposed.

The ability to collect and analyze big data has played a revolutionary role in almost every field, the agriculture is no exception. The key is turning that vast amount of big data into actionable data that can be gleaned from advanced analytics systems to assist farmers in making more informed decisions. Since datasets may originate from different sources, it is key for data to be properly ingested, cleansed, and harmonized using AI and advanced analytics to obtain the insights for practical solutions to a farmer's specific challenges. It is important to mention that in the past farmers lacked the data-driven insights to combat dwindling resources, pests, and changing weather conditions, and now the agricultural workers will have the ability to monitor and analyze crops in real-time leads to data-driven decision making with informed conclusions. The precise knowledge and understanding of when and where to use irrigation, fertilizers, and herbicides lead to healthier crops and higher yields. Agriculture 4.0 can provide solutions to optimize agricultural data management, enabling yield increase, improve crop management, boost productivity, and operate more sustainably.

5. Conclusions

The transition to digital agriculture implies changes in the practices and ways of doing business of actors in the entire chain of agricultural production. The introduction of new technologies leads to a redistribution of activities and resources with a pronounced need for the development of new skills and competencies. Digitalization has ushered in a new era of agricultural transformation with digital platforms emerging as an important part of this dynamic, opening up a wide range of opportunities to address sustainability issues that remain underexplored.

Today we are faced with numerous issues such as information and communication technology, digitalization, smart agriculture, Internet of Things, variable speed systems, sensor technologies and even business management through mobile phones. In this paper the authors have investigated the agricultural digital transformation in the view of the Agriculture 4.0 and therefore conclude that it also imposes adequate agricultural policy instruments that address problems of sustainability in agriculture more effectively and efficiently, especially for countries where agriculture plays a dominant role in their national economy, i.e. in the creation of gross domestic product and gross added value. It is extremely important that the agricultural policy promotes the digitalization for agricultural producers and defines which areas are open for development for the sustainable agriculture business. However, in the Republic of Serbia there is a significant gap in knowledge in this area. There are no instruments that would measure the level of digitalization of agricultural production, especially with regard to smart and precision agriculture technologies. Several studies conducted so far have used different indicators to detect the level of digitalization of farmers, but there are no studies to determine the level of digitalization in all aspects.

Conflicts of Interest: The authors declares no conflict of interest.

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