Smart Agriculture Development and Its Contribution to the Sustainable Digital Transformation of the Agri-Food Sector

Darko Lugonja, Mladen Jurišić, Ivan Plaščak, Ivana Zbukvić, Danijela Glavica-Tominić, Ivan Krušelj, Dorijan Radočaj*

Abstract: This study analyses the importance of the connection between the development of smart agriculture and sustainable digital transformation (DT) of the agri-food sector. The sustainability of DT depends on a number of complex components, especially information and communication technologies (ICT), and economic systems. The increase in the number of studies in this area indicates a complex nature as well as interdependencies. Over the last few decades of innovation, ICT, artificial intelligence (AI) and the Internet of Things (IoT) have significantly affected human activities in all aspects. This includes the rapidly changing and difficult-to-predict agricultural sector in the context of global development, indicating the need to address these challenges. The global trend of DT has included all sectors, opening space for the contribution of smart agriculture to sustainable DT, but also to find appropriate "tailor-made solutions" for every challenge we face.

Keywords: Artificial Intelligence (AI); Digital Transformation (DT); Information and Communication Technologies (ICT); Internet of Things (IoT); Smart Agriculture

1 INTRODUCTION

The expansion of the Internet of Things (IoT) in all sectors, including agriculture, has led to a new concept of the Internet of Everything (IoE) [1]. Smart cities and smart villages, as a concept in development, presuppose a holistic and multidisciplinary approach to all challenges of new technologies and paradigms, including in the agricultural sector. Trends of smart urban and/or rural communities regarding the development of sustainable digital transformation (DT) indicate the importance of development, but also the impact of the connection between the system and infrastructure. Håkansson [2] points to the importance of the systematic, "tailor-made" and sustainable application of information and communication technologies (ICT) in the development of smart cities, bearing in mind the importance and expectations of all stakeholders, as well as their needs. O'Grady et al. [3] emphasized the importance of harmonizing all technological aspects, but also their further connection and appropriate application and further development. Continuously, taking into account all aspects of change management, but also the complexity of the challenge, this is focused on the contribution of innovative technologies in agriculture and DT, and showing the impact of new phenomena such as smart agriculture.

Consequently, it is necessary to take into account all trends, specifics, business and other related conditions, in order to provide an appropriate "tailor-made" solution and include all aspects and impacts [4]. Research in the conditions of "Living Laboratories" and their impact on DT confirms this [5]. The aim of this paper is to present the links and inter-impacts of smart agriculture and sustainable digital transformation.

2 DIGITAL TRANSFORMATION IN AGRICULTURE

Agriculture has a primary role in meeting global nutrition needs. During the past two decades food and agriculture sector have passed through the dramatic changes

The mentioned changes ensured successful achievement in overcoming growing challenges in various areas of food and agriculture production – safety, sustainability and health. Those changes were provided by improvements in application of the non-digital technologies such as mechanization, animal and plant breeding, and environmentally friendly farming methods. Regardless of the mentioned challenges and solutions, improvements in agricultural productivity are expected to be increased in order to ensure planned development, improvements and maintenance that may cover the needs of growing world populations. Accordingly, this has to be followed in solutions and actions towards climate changes, animal welfare, recovery efficiency, food health and safety, as well as critical changes in human behaviour. As DT is taken into account in terms of technical and technological aspects, it is necessary to emphasize the importance of non-technological aspects and components at the outset. DT is defined as a profound transformation of business and organizational activities, processes, competencies and models to take full advantage of the changes and opportunities of digital technology combinations on society in a strategic and priority way [6]. The technological and especially non-technological aspect of DT needs to be considered because of the integration of DT into the life of individuals and organizations, in urban and rural environments. A review of DT through a series of case studies and studies is provided in [7, 8].

Three procedure groups stand out with the aim of ensuring a sustainable and comprehensive approach:

- Replacement (where digital technologies replace an existing function or procedure),
- Expansion (where digital technologies improve the functionality of an existing process or product),
- Transformation (where digital technologies basically redefine or create a new process or product).

In DT, organization are passing through the systematic, overall group of changes of the business system, including companies, business models, processes, relationships and

products [9]. This leads most of the cultural and organizational changes needed to use new digital technologies to enable great improvement. Some of these are better user experiences, streamlining business and innovating products or services and business models, as well as improving business performance [10]. DT is a set of changes brought about by digital technologies at the operational level through product improvements, organizational structure or through automation processes [11]. In addition, DT influences social processes through changes in strategy and transformations of business activities, processes, competencies, and overall business models [12].

The intention of agricultural and other producers has ensured a successful digital transformation in order to provide a new offer. These improve the existing offer of customers or users, and the technology itself is crucial in operational terms, but also part of the same offer. This further involves investing in technology and a business model to effectively address all customer or user requirements and expectations, at all times during the product lifecycle [13]. The IoT as an approach toned to provide the significant increase in productivity, a potential to achieve higher levels of control. Digital agriculture would therefore be a set of systems for collecting, processing and transmitting data with the aim of faster, easier and simpler management of systems in agricultural and food production. Because the impact on DT is set, significant, and growing, it takes into account and influences business processes and maintains the management and changes it manages [14]. Recent research points to the impact of DT on the industry, and numerous case studies noted a contingency approach, especially in real-life situations and consideration of the critical aspect of DT [15]. The recent work of Tomičić Furjan et al. [7] presents models and technological concepts or factors relevant to the DT initiative, as well as holders and expectations related to DT.

Considering the maturity of DT, all determinants to enhance and ensure the development and maturity of DT should be considered. The most common ones are:
- Strategic determinants,
- Customer/user focus,
- ICT and process infrastructure,
- Talent, abilities and capacity building,
- Innovation culture and organizational commitment.

Stakeholders, employees and others should "live" in this transformation, and everyone should be involved in processes and in an environment that supports innovation and change [16]. DT is challenging for both urban and rural areas, due to a range of social, political, economic and historical conditions, for example, the elderly population. Despite promising growth trends, an insufficient number of young farmers, critical infrastructure and decision-makers are not sufficient to support the change. Among the various influences on DT drivers, given the creation of a business model, there is a strong need to consider the drivers of change management in DT [17]. Not only the benefits, but also numerous challenges are related to DT and its impact on change in almost every aspect. They are identified and described as "potential problems" and can be classified as challenges, or obstacles, depending on the difficulty and time dimension, which is provided in the next steps [15]. The McKinsey Global Survey on Digital Transformation [18], showed the problems and new opportunities in digital transformation from different aspects.

3 SMART AGRICULTURE AND IoT

The architecture of food and agricultural systems based on IoT includes a number of opportunities for the development of IoT in the direction of agriculture and other industries. It is expected that the IoT could bring significant changes in food production and agriculture, with possible challenges such as overcoming difficulties such as addressing its heterogeneity. Digital Agriculture 4.0 aims to provide sustainable framework for modelling IoT systems in each industry, especially food and agricultural production [19]. The inclusion of the IoT at the macro and micro levels allows for gradual but also rapid change, depending on the goals, strategies and policies that have adopted the need for change in all sectors and activities.

The IoT in smart agriculture allows [20]:
- Monitoring and control of production and its development,
- A better analysis and improvement of the process,
- Easier interpretation and further research of all phases, processes and aspects of production,
- Easier definition and monitoring of quality standards,
- Improving quality and monitoring quantity,
- Development of consumer awareness and education at all levels.

IoT application may open various challenges, food and agriculture depend on natural conditions too often, being under the influence of weather conditions and diseases [21]. In addition, there are many different types of production, such as farming, organic farming, greenhouse farming, or animal husbandry.

Farmers have to deal with a number of interconnected facilities such as:
1) Intake and costs, seeds, fodder, fertilizers or pesticides;
2) agricultural land, barns, tractors and equipment;
3) animals, food and fresh produce;
4) Logistics, transport, packaging, containers and trucks.

In order to provide a solution for such a heterogeneity providers need to ensure interoperable nodes within a newly developed ecosystem [22, 23]. Newly built IoT systems must provide interoperable nodes within a well-coordinated software ecosystem maximizing the repeated utilization and synergy across multiple IoT systems. IoT-based systems are now integrated in a coherent way, leading to the System of Systems (SoS) [24]. In the development of IoT applications in agriculture one of the possible approaches, which provide the greatest development opportunities is the SoS [20].

4 INNOVATIONS AND TRENDS IN SMART AGRICULTURE

The rapid advance of geoinformation technologies, including novel remote sensing approaches using unmanned aerial vehicles (UAVs), allowed their integration in the decision-making processes even for small farmers [25]. This resulted in the availability of a large amount of image data at the micro-level, as well as a high degree of compatibility with IoT. A wide selection of sensors suitable for the integration with the UAVs covers the majority of the requirements for spatial data collection in agricultural production. While their cost prevented the farmers from obtaining them individually, presently RGB, multispectral, radar and LiDAR sensors are commercially available at reasonable prices. Due to the high computation requirements of aggregating these data in agricultural land management and precision agriculture, big data solutions will likely become more necessary in smart agriculture.

The emergence of the machine learning algorithms enabled a superior accuracy and computational efficiency of cropland suitability and soil parameters prediction compared to the conventional methods [26]. These methods would likely become gradually more instrumental to the efficient agricultural land management planning as a basis for smart agriculture. Moreover, the effects of climate change will eventually require the introduction of new crop rotation systems, making a suitability analysis focal point of the new land management plans. The computational efficiency of machine learning methods also opened more possibilities to additional exploitations of data sources that was previously under-utilized, such as satellite multispectral imagery [27]. These data enable efficient monitoring of large continuous areas, providing a possibility for more efficient agricultural subsidy control systems and detecting soil degradation.

The overall trends in smart agriculture will presumably be oriented towards the end-user, allowing small farmers to actively collect data regarding their farms and process them in real-time. With the availability of exponentially higher data count, new unbiased observations regarding agricultural production efficiency will be explored [28]. Ultimately, smart agriculture would be oriented to the adaptation to increasing food production by implementing state-of-the-art ICT solutions.

5 CONCLUSION

The core of DT is a deep transformation of business and organizational activities, processes, competencies and models. These components fulfil the necessity to take full advantage of the changes and opportunities of digital technology combinations. Their accelerating impact on society acts in a strategic and priority way, keeping in mind current and future shifts. Aside from the general DT, the implementation of the ICT in new agricultural projects should be further subsidized, leading to a more efficient agri-food sector. Digital agriculture could be described as a set of systems for collecting, processing and transmitting data with the aim of faster, easier and simpler management of systems in agricultural and food production. The digital transformation of agriculture, like most other activities, is based on several things on the Internet, but also the development of a set of systems, through the SoS.

The advantages brought by these new systems and changes, as well as considerable challenges, lead to an increasing need for education and the adoption of increasingly complex and diverse knowledge. This especially refers to the spatial component of smart agriculture by integrating modern geoinformation technologies into agricultural production. The farmers are referred to an increasing number of professional sources in development and production planning, which will ultimately increase the efficiency of agricultural production.

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Authors' contacts:

Darko Lugonja, MSc
Ministry of Agriculture, Department for Professional Support to the Development of Agriculture and Fisheries
Ul. grada Vukovara 78, 10000 Zagreb, Croatia
E-mail: darko.lugonja@mps.hr

Mladen Jurišić, PhD, Full professor
Josip Juraj Strossmayer University of Osijek,
Faculty of Agrobiotechnical Sciences Osijek
Vladimira Preloga 1, 31000 Osijek, Croatia
E-mail: mjurisic@fazos.hr

Ivan Plaščak, PhD, Associate professor
Josip Juraj Strossmayer University of Osijek,
Faculty of Agrobiotechnical Sciences Osijek
Vladimira Preloga 1, 31000 Osijek, Croatia
E-mail: iplascak@fazos.hr

Ivana Zbukvić, MSc
Ministry of Agriculture, Department for Professional Support to the Development of Agriculture and Fisheries
Ul. grada Vukovara 78, 10000 Zagreb, Croatia
E-mail: ivana.zbukvic@mps.hr

Danijela Glavica-Tominić, MSc
Ministry of Agriculture, Department for Professional Support to the Development of Agriculture and Fisheries
Ul. grada Vukovara 78, 10000 Zagreb, Croatia
E-mail: Danijela.G-Tominic@mps.hr

Ivan Krušelj, MSc
Ministry of Agriculture, Department for Professional Support to the Development of Agriculture and Fisheries
Ul. grada Vukovara 78, 10000 Zagreb, Croatia
E-mail: ivan.kruselj@mps.hr

Dorijan Radočaj, MSc
(Corresponding author)
Josip Juraj Strossmayer University of Osijek,
Faculty of Agrobiotechnical Sciences Osijek
Vladimira Preloga 1, 31000 Osijek, Croatia
E-mail: dradocaj@fazos.hr