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DIGITAL AGRICULTURE - TECHNOLOGICAL MEANS AND POSSIBILITIES OF DIGITAL TRANSFORMATION OF AGRICULTURE

Giorgi Abashidze[1], Ph.D Student

[1]Batumi Shota Rustaveli State University

Abstract. In the last 20 years, the extensive integration of digital technologies has led to considerable changes in all industries, including agriculture. As a result, the agricultural sector has undergone a digital transformation. This shift has become increasingly necessary due to the many challenges faced by modern-day agriculture, such as rising temperatures, changing seasons, frequent extreme weather conditions, low availability of water resources, and decreased soil fertility. It is now evident that traditional farming methods are inadequate for achieving efficiency in agriculture, and innovative methods are essential. One such approach is digital agriculture, also known as smart agriculture or e-agriculture. This cutting-edge method utilizes digital technologies to collect, process, analyze, and disseminate information, enabling real-time decision-making in response to changing external factors.

Considering given factors, the paper discusses the main directions of the digital economy that could impact agriculture. It evaluates existing examples and models of digital agriculture, while identifying possible ways to apply digital technologies in the agricultural sector. Based on thorough research, the final section of the paper offers practical recommendations that can serve as useful tools for developing countries as they transition towards the digital transformation of agriculture. The research findings make it clear that digital technologies have become a critical component of modern-day agricultural activities. Without their integration, it would be impossible to sustain productive agricultural activities, meet the global demand for food, and respond adequately to changing environmental factors.

Key words: digital agriculture, e-agriculture, digital economy, technological revolution.

JEL code: Q16, O13, O31

Introduction

Digital agriculture entails the use of digital technologies to facilitate information collection, processing, analysis, delivery, and decision-making in response to changing external factors. This approach also encompasses the concept of precision agriculture, which is a management technique that involves observation, measurement, information gathering, analysis, and the implementation of predetermined actions. The ultimate objective of precision agriculture is to establish a robust decision-making system (DSS) that can effectively manage agricultural operations.

Currently, farmers primarily rely on personal experience, recommendations, and advice when making decisions about various agricultural operations, such as the amount and combination of fertilizers to use, the rate of planting seedlings, and the timing of such activities. However, a digital agriculture system provides more accurate and frequent data regarding the condition of the agricultural land. This data is then analyzed and interpreted to help farmers make more informed decisions. With the aid of robotics and artificial intelligence, these decisions can also be made faster and with greater accuracy. In the agricultural sector, various technologies are utilized such as sensors, communication networks, unmanned aerial systems (UAS), artificial intelligence (AI), the Internet of Things (IoT), and other advanced technologies. The utilization of these technologies offers solutions to the main challenges faced by agriculture, including increasing yields of agricultural lands, efficient harvesting, ensuring crop and livestock care, and promoting sustainable agriculture. Meeting the United Nations Sustainable Development Goal of achieving a 'world with zero hunger' by 2030 requires food systems that are more productive, efficient, sustainable, inclusive, transparent, and resilient (FAO, 2017). Digital agriculture has the potential to enhance agriculture by making it more productive, consistent, and resource-efficient. These advantages are not only beneficial for farmers but also offer social benefits for the wider society. Taking into account the challenges faced by the

[1] E-mail: abashidzegiorgi@outlook.com; giorgi.abashidze@bsu.edu.ge, Tel.: +995 577 00 25 37

agricultural sector, such as rising temperatures, changing seasons, frequent extreme weather conditions, low availability of water resources, and decreased soil fertility, it is crucial to investigate methods of ensuring the sustainability and enhancing the efficiency of agricultural activities. The main objective of this paper is to study the means of achieving these goals and maximizing the benefits of agricultural activities.

To accomplish this, the paper centers on the discussion of digital transformation methods for agricultural activities, presentation of existing models, and evaluation of their effectiveness in regards to sustainability and efficiency. The latest literature in this field has been thoroughly examined within the framework of this work, and statistical data analysis, grouping, and modeling techniques have been employed. The discussion includes a detailed examination of selected countries that have already made significant strides in digitalizing agriculture. Additionally, strategies for digitalizing agriculture are described and current models are evaluated.

Research results and discussion

1. Tools for the digitization of agriculture in the digital economy

There are several primary directions that form the foundation of the digital economy and establish the necessary digital infrastructure for the digitization of various sectors and industries, including agriculture:

Information and Communication Technologies (ICT) - encompass various types of equipment and services that facilitate broadcasting, computing, telecommunications, information processing, and display (OECD, 2020). This includes communication equipment such as radio, television, mobile phones, computer and network equipment, and satellite systems. ICT serves as the foundation for people to utilize other components of the digital economy. It is crucial for the population to have internet access in order to fully benefit from these advancements; however, this remains a significant challenge in most developing countries.

Big data - big data refers to a collection of data that exceeds the capacity of traditional databases to efficiently gather, manage, and process within a short period of time. The emergence of artificial intelligence (AI), mobile devices, social media, and the Internet of Things (IoT) have led to the creation of increasingly complex data sources that contribute to the formation of these large databases. Big data has the potential to facilitate the development of new products, optimize services and processes, improve decision-making mechanisms, and enhance forecasting and market research. In the realm of digital agriculture, big data can enable farmers to make informed decisions based on data collected throughout the year, in addition to taking environmental factors into account, rather than solely relying on personal knowledge and experience. This can result in more accurate and effective decision-making in the agricultural process.

Artificial intelligence - AI is the ability of a machine, or a robot, to act to achieve a goal while taking external factors into account. The development of artificial intelligence has become possible based on the processing of a large amount of information, which allows the development of behavioral algorithms and scenarios. A good example of artificial intelligence is self-driving cars, search engines, etc. A subset of artificial intelligence is machine learning, which refers to the concept that computer programs can automatically learn and adapt to new data without the help of humans. Deep learning techniques allow the machine to use a huge amount of unstructured information (text, image, video) in the learning process. Artificial intelligence provides a significant opportunity to automate numerous processes in agriculture. Through the use of AI, it is possible to swiftly adjust the intensity of agricultural activities, methods, and approaches based on information regarding weather, soil, seasons, and other external factors, in addition to existing data available on the Internet.

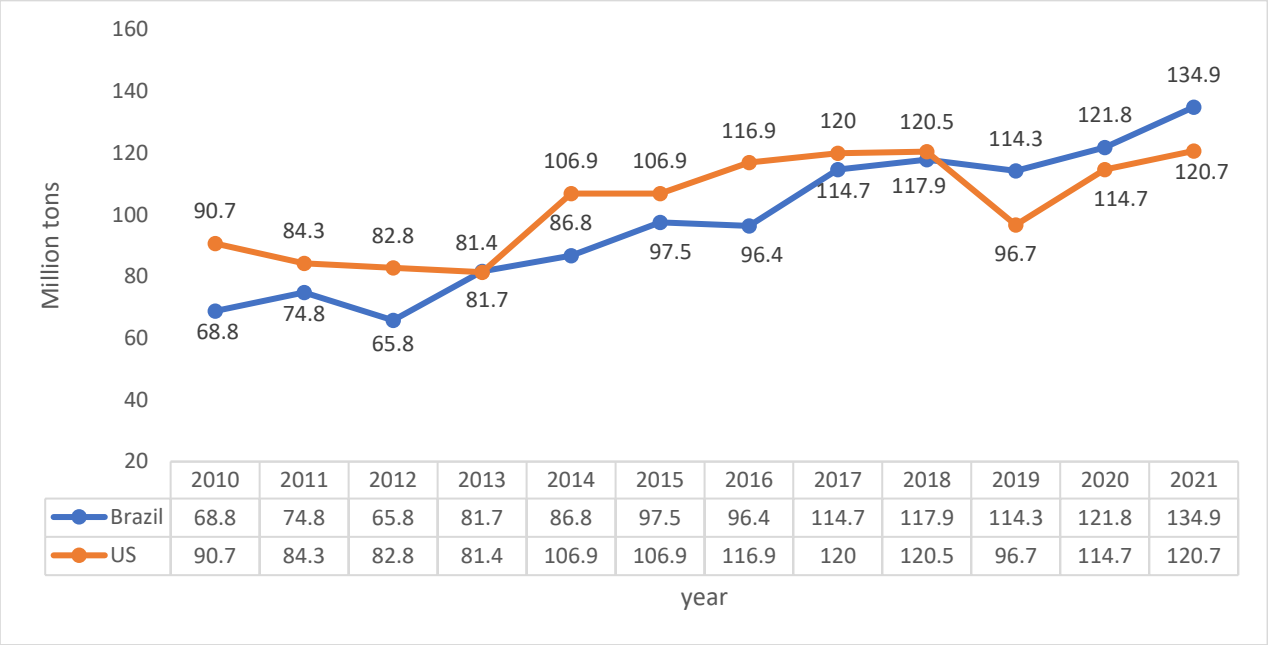
Internet of Things - IOT refers to interconnected devices that form a single intelligent ecosystem, where communication between devices included in the ecosystem is established through the sensors in the devices. It is a smart ecosystem that can be managed remotely via the Internet (Body of European Regulators for Electronic Communications, 2019). The IOT system can monitor a wide range of processes and, if necessary, make a decision independently without human intervention. IOT systems are successfully used for managing the existing infrastructure within the business, for the smooth operation of security systems, for regulating traffic flows on roads, and for monitoring soil, moisture, weather, and other related processes in agriculture. McKinsey Global Institute estimates that artificial intelligence has the potential to increase the world's gross domestic product by 26% until 2030. In the first quarter of 2022, the number of unique mobile network subscribers was 5.3 billion, with 10.6 billion devices connected to the network (GSMA, 2022).

Cloud computing - Cloud computing is a service that offers various types of online computing resources, such as software and memory, to users. This resource significantly reduces costs, increases flexibility and productivity, and provides higher safety and security. Farmers can benefit from more flexible digital solutions and economies of scale through cloud-based connectivity, which uses a live internet connection. Implementing cloud connectivity is a significant enhancement that allows farmers to observe and take action in real-time.

Automation and robotization - Nowadays, it is challenging to envision efficacious agricultural practices without resorting to robots and unmanned aerial systems. Robots and drones are proficient in facilitating tasks such as planting, harvesting, weed control, cleaning, and more. Furthermore, agricultural machinery has been notably efficient in livestock care. The International Federation of Robotics reported that the utilization of industrial robots has been steadily rising at an average of 10% per annum since 2010, with a total of 3.014.879 in operation as of 2020 (The International Federation of Robotics, 2021).

2. How can agriculture be digitally transformed?

Information holds paramount importance in agriculture. It is a domain that assimilates digital technologies effortlessly, and generates vast amounts of data. As we comprehend, information is a crucial production resource, pivotal in determining the prosperity of a company or nation. This aspect is particularly crucial in the digital economy era. As an example, Brazil is currently the world's foremost producer of soybeans. However, just a decade ago, the scenario was vastly different as Brazil only produced half of what it does today. In the past decade, Brazil has successfully doubled its production while simultaneously maintaining its current cost per hectare indicator ($324), which is 12% less than the same metric in America. The Brazilian Agricultural Research Organization (EMBRAPA) credits this accomplishment to the effective processing of information derived from farms, utilizing the technique of data analysis. Farmers leverage data-supported seed placement to make informed decisions regarding seed selection, seeding technology, intensity, placement, and crop care for the forthcoming season. This method is not based solely on information from the previous year but employs artificial intelligence to process and optimize the given information.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Brazil	68.8	74.8	65.8	81.7	86.8	97.5	96.4	114.7	117.9	114.3	121.8	134.9
US	90.7	84.3	82.8	81.4	106.9	106.9	116.9	120	120.5	96.7	114.7	120.7

Source: FAOSTAT, EMBRAPA, 2022

Fig. 1. **Soybean production in the US and Brazil, 2010 - 2020**

Currently, there exists an unprecedented opportunity for the digital transformation of agriculture, facilitated by visualization technologies that enable the creation of maps displaying temperature, fertility, and moisture gradients across the land. This allows for precise, individualized treatment of each section of the land. Variable rate applications (VRA) play a vital role in this regard, with sensor or map-based options available. In map-based VRA, a map created beforehand by the farmer is utilized as a data source.

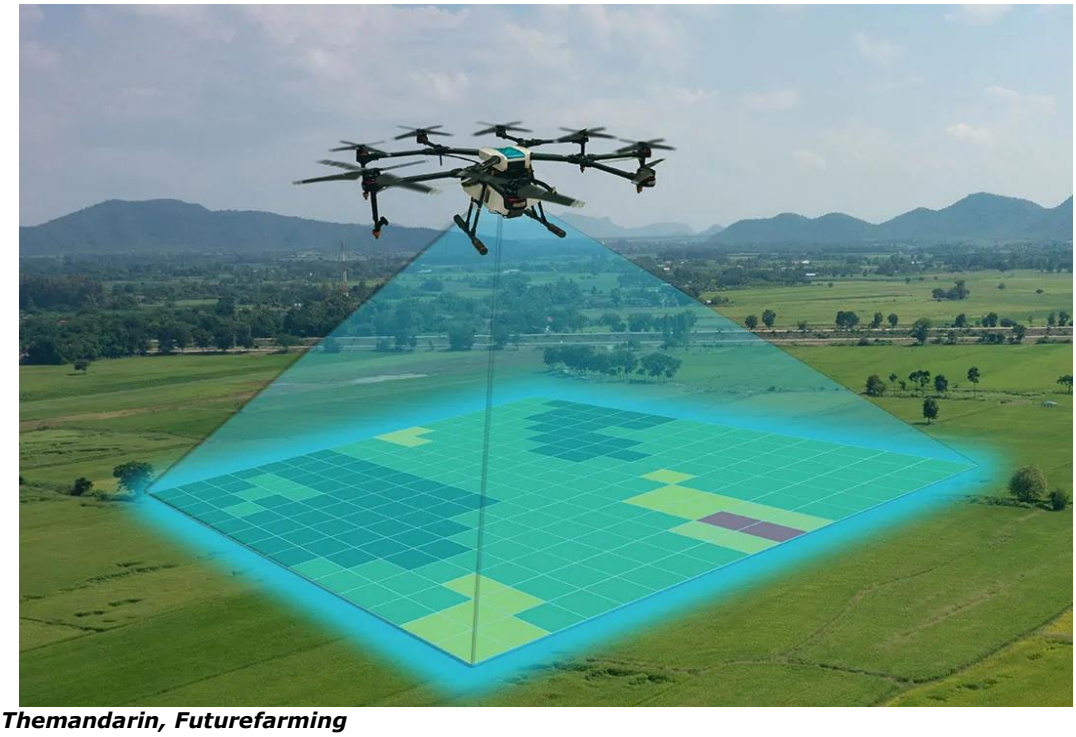
Some examples of VRA

Sowing with variable rate - this method permits the alteration of the rate, distance, amount, and depth of sowing. By utilizing variable-rate sowing, adjustments can be made to accommodate variations in soil conditions. Even on small plots of land, differences in soil structure can exist across sections, necessitating customized sowing techniques.

Weed control with variable rate - by collecting information from soil sensors, this method enables early identification of weeds in the soil, assessment of their intensity, and implementation of appropriate countermeasures.

Fertilizer supply with variable rate - plants do not always require the same amount of fertilizer, and the soil composition can vary across different parts of the land. A comprehensive approach is therefore required, which is provided by a variable-rate fertilizer delivery mechanism that utilizes sensors, climatic conditions, and GPS technology to adjust the amount of fertilizer delivered to various parts of the land. The land can be divided into desired-sized squares for this purpose.

Artificial intelligence, machine learning, agro-guide applications, precision agriculture technologies GPS, GNSS, RFID, IOT, sensors (weather, soil, plant) and, of course, variable rate technologies are successfully used to reduce costs and increase efficiency in agriculture.



Source: Themandarin, Futurefarming

Fig. 2. **Agricultural lend division based on variable rate applications**

Today, the utilization of solar-powered robots and drones in agriculture has become increasingly prevalent, enabling the automation of land processing and harvesting procedures. Drones provide high-resolution visualizations of the land, aiding in the assessment of land conditions, yield levels, rainwater drainage channels, and more. The Internet of Things (IoT) is crucial to the digital transformation of agriculture, enabling sensor usage and the development of farm management software packages. For instance, IoT technology makes it possible to assess soil composition spectroscopically, reducing fertilizer use by up to 30% (M. Sophocleous and J. K. Atkinson, 2015).

These technologies are not limited to horticulture, as they are also successfully applied in animal husbandry. Animals can be equipped with internal and external sensors that assess their digestive system, organ health, movement patterns, external injuries, and optimal reproductive timing. The collected information is communicated to the farmer, leading to data-driven decision-making and accurate farming operations.

Monitoring technologies are also employed in beekeeping, using sensors to monitor temperature, humidity, CO_2 levels, and colony health. This enables early identification of potential problems in the colony and the implementation of effective solutions.

Additionally, smartphones and tablets are increasingly being used in modern agriculture, with a range of applications designed for agriculture, such as yield map makers, animal movement monitors, and GPS systems.

Lastly, machine learning technologies are used to effectively process information from various sources, creating a unique farm management system that automates a wide range of processes and enhances decision-making. These technologies significantly improve farm efficiency and reduce costs.

Conclusions, proposals, recommendations

The article highlights the importance of digital agriculture in addressing the many challenges facing the agricultural sector today. The integration of digital technologies has led to significant changes in all industries, including agriculture, and has become increasingly necessary to achieve efficiency in agricultural

activities. The article also highlights the different directions of the digital economy that could impact agriculture and evaluates existing examples and models of digital agriculture.

The practical recommendations offered in the final section of the paper can serve as useful tools for developing countries as they transition towards the digital transformation of agriculture. The research findings make it clear that digital technologies have become a critical component of modern-day agricultural activities. Without their integration, it would be impossible to sustain productive agricultural activities, meet the global demand for food, and respond adequately to changing environmental factors.

Therefore, it is recommended that governments, private sector actors, and other stakeholders prioritize investments in digital agriculture to promote sustainable agricultural activities. This could include investments in research and development, technology transfer, infrastructure development, and capacity building. Governments should also create an enabling environment for the adoption of digital technologies in agriculture by providing regulatory frameworks, promoting public-private partnerships, and ensuring access to affordable digital services.

Digital tools offer farmers a range of benefits, including improved communication with other farmers at regional and national levels, effective farm monitoring, informed decision-making, and time and cost savings. In today's modern world, these tools are essential for agricultural activity. However, farmers are often accustomed to traditional methods and may struggle to embrace technological innovations due to negative associations. To address this, the government must play a key role. It is essential to increase public access to digital technologies while also equipping society with the necessary knowledge and skills to use them effectively. These processes must go hand in hand, and the government should take steps to ensure that farms have access to digital tools and the skills required to use them.

In summary, the digital transformation of agriculture has become a necessity for sustainable agricultural activities. It is crucial that stakeholders prioritize investments in digital agriculture to promote efficiency and productivity, meet the global demand for food, and respond adequately to changing environmental factors.

1) Efficient agricultural activities cannot be ensured today without the integration of digital technologies.
2) The utilization of digital technologies offers an opportunity to enhance productivity and decrease costs per hectare.
3) Adequate digital knowledge and skills within society are crucial to fully harness the benefits of digital technologies in agriculture.
4) Government involvement is essential in facilitating the digital transformation of agriculture.
5) All segments of the agricultural value chain should be engaged in the digital transformation process.
6) They enable real-time decision-making in response to changing environmental factors.
7) The digital transformation of agriculture is necessary to sustain productive agricultural activities.
8) Digital agriculture can help address the challenges facing the agricultural sector, such as rising temperatures, changing seasons, and decreased soil fertility.
9) The integration of digital technologies can result in higher yields, reduced costs, and more sustainable agricultural practices.
10) Digital knowledge and skills are necessary for individuals and organizations to fully benefit from digital agriculture.
11) Governments play a crucial role in facilitating the adoption of digital technologies in agriculture.

12) The digital transformation of agriculture requires the involvement of all segments of the agricultural value chain, including farmers, agribusinesses, and input suppliers.

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Bibliography

1. AgFunder (2017, 6). Putting a Price on Farm Data. Retrieved from: agfundernews.com: https://agfundernews.com/putting-price-farm-data.html
2. Body of European Regulators for Electronic Communications (2019, 3). Internet of Things indicators. Retrieved from: berec.europa.eu: https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8464-berec-report-on-internet-of-things-indicators
3. Yield (2022). Delivering your Digital Playbook, Make the right decisions, at the right time. Retrieved from: www.theyield.com: https://www.theyield.com/our-solution
4. Food and Agriculture Organization of the United Nations (2022). *Digital Agriculture*. Retrieved from: https://www.fao.org/digital-agriculture/en/.
5. Food and Agriculture Organization of the United Nations (2019). DIGITAL TECHNOLOGIES IN AGRICULTURE AND RURAL AREAS. Retrieved from: https://www.fao.org/3/ca4887en/ca4887en.pdf.
6. Food and Agriculture Organization of the United Nations (2017). E-AGRICULTURE IN ACTION. Retrieved from: https://www.fao.org/3/i6972e/i6972e.pdf.
7. Cultivating New Frontiers in Agriculture (s.a.). DIGITAL AGRICULTURE. Retrieved from https://www.cnfa.org/digital-agriculture-solutions/.
8. United states department of agriculture (2018, 6). Economic, statistics ad market information system. Retrieved from: usda.library.cornell.edu: https://usda.library.cornell.edu/about?locale=en
9. Emma Ea Ambrose (2020). What is digital agriculture?, Retrieved from: https://ag.purdue.edu/stories/digital-agriculture-why-the-future-is-now/
10. Organisation for Economic Co-operation and Development (2020). New technologies and digitalisation are transforming agriculture and offering new opportunities to improve policy Retrieved from https://www.oecd.org/agriculture/topics/technology-and-digital-agriculture/
11. Food and Agriculture Organization of the United Nations (2020). Artificial Intelligence best-practices in agriculture can help bridge the digital divide while tackling food insecurity Retrieved from https://www.fao.org/news/story/en/item/1309630/icode/
12. European Commission (2023). The Digitalisation of the European Agricultural Sector, Retrieved from https://digital-strategy.ec.europa.eu/en/policies/digitalisation-agriculture
13. UNDP (2019). Sustainable and Digital Agriculture, Retrieved from https://www.undp.org/sgtechcentre/sustainable-and-digital-agriculture-1
14. Klerkx, L., E. Jakku, and P. Labarthe (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda."NJAS-Wageningen Journal of Life Sciences.
15. Delgado, J. A., Short Jr, N. M., Roberts, D. P., & Vandenberg, B. (2019). Big data analysis for sustainable agriculture on a geospatial cloud framework. Frontiers in Sustainable Food Systems, 3, 54.
16. International Society of Precision Agriculture (2021). Precision Agriculture Definition Retrieved from: https://www.ispag.org/about/definition