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IMPORTANT ASPECTS OF THE USE OF DIGITAL TECHNOLOGIES IN AGRICULTURE AND WATER MANAGEMENT IN FOREIGN COUNTRIES

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Abstract

Digital technologies provide increased productivity, cost optimization, and sustainable development of agriculture. The article presents the experience of successful countries in the digitalization of agriculture and water management, and also includes a description of government support measures for the development of digitalization in the water sector in the European Union, USA, Germany, Chile, Poland, Turkey, Israel, and digital services in the agricultural sector.

Keywords: *digital economy, technology, e-commerce, dot-com, digital platforms, infrastructure, irrigation, drivers, transaction costs.*

Introduction. To increase productivity, agriculture has evolved from foraging to cultivating fields and crops, to using fertilizers and mechanization, and to the automation of production. A new technological stage has now emerged: the introduction of digital technologies. Beyond the traditional goals of improving productivity, product quality, reducing production losses, and energy consumption, new opportunities have surfaced. These include digital data collection on crop and livestock conditions, detailed down to specific fields or animals in real-time, optimized fertilizer and pesticide application schemes, the introduction of "smart" agricultural machinery, and artificial intelligence technologies, among others. In other words, digitalization offers each farmer answers to critical questions: how to achieve higher crop yields and livestock productivity from one hectare while minimizing both human and material resources.

However, there are constraining factors: underdeveloped infrastructure, outdated agronomist educational programs, and financing challenges. Staying on the sidelines of digital transformation risks losing competitiveness. Therefore, the state's role in implementing a complex set of stimulating and regulatory measures becomes significant. The integration of such measures will define the successful adoption of digital technologies in agriculture. These measures include:

1. Developing digital infrastructure (e.g., internet access);
2. Modernizing the education system and creating new training programs;
3. Simplified financing systems for innovations;
4. Government regulation;
5. Digitalizing state support processes for agriculture.

Digitalizing agriculture is crucial for enhancing its efficiency and sustainability by radically improving the quality of management of technological processes and decision-making at all levels. This relies on modern methods of production and the use of information on the state and forecasting of possible changes in controllable elements, subsystems, and economic conditions in agriculture. Currently, digital agriculture ranks first globally in terms of the potential positive impact of global technologies.

A key task in digital agricultural transformation is deriving value from the vast data collected on internal and external environments. This relies on cloud platforms, big data processing solutions, predictive analytics technologies, and decision-support systems.

The application of sensory equipment (e.g., field sensors, production facility monitors, agricultural equipment trackers, livestock health monitors) enables many agricultural enterprises to continuously collect and analyze information, integrating three levels of agrosystem monitoring (ground, aerial, and space-based) at the farm, regional, and national levels.

Digital technologies also reduce agriculture's ecological footprint, enhance resource efficiency, and lay the foundation for ESG (Environmental, Social, and Corporate Governance) strategies, which likely remain integral to the agricultural development agenda. Digitalization addresses sector weaknesses such as crop losses due to unpredictable weather, inefficiencies in cultivation, harvesting, and storage. It facilitates the prompt monitoring of fields, reduces theft of materials, fuel, pesticides, and seeds, and streamlines product sales and state support mechanisms.

Even with existing infrastructure challenges that hinder the full use of digital equipment, large and medium businesses are making strides in digital transformation. Amid pandemics or shifting consumer preferences, the green economy, digital technologies, and artificial intelligence offer solutions for analyzing market trends, ensuring product orders and delivery, as well as maintaining the quality and safety of raw materials and products while reducing costs and carbon footprints.

Methodology. In researching this topic, the authors applied methods such as analysis, observation, comparison, and biological review.

Discussion. Below, we examine the experiences of successful countries in the digitalization of agriculture and water management.

United States of America. The U.S. government

focuses on various aspects of agricultural digitalization: precision farming, digital financial services, data management systems, support for information technology, and more. The U.S. has a centralized agricultural research system regulated by the National Institute of Food and Agriculture under the U.S. Department of Agriculture (USDA). The institute regularly conducts research on digitalization by providing grants. The country consistently ranks among the leaders in global digitalization indices, such as third place in the Global Innovation Index.

Netherlands. Optimized production processes using digital technologies, efficient logistics, and high labor productivity have positioned the Netherlands as a global leader. The “Food Valley,” centered around Wageningen University, has propelled the country to top ranks in food export and digitalization indices. Dutch agricultural exports have exceeded $100 billion annually, with the country ranking first in the Network Readiness Index as of 2020.

The country has achieved great success in agricultural technologies and innovations that continue to increase productivity and exports. In 2020, Dutch agricultural exports totaled $104.7 billion, second only to the United States with $149.3 billion. These export volumes are the result of innovative and digital approaches to agriculture, trade, and logistics, as evidenced by the Netherlands' high positions in international rankings.

Dutch greenhouses are a hallmark of the country’s agricultural sector. The synergy of greenhouse farms and digital technologies has enabled the Netherlands, a country just over 40,000 square kilometers in size, to become the largest exporter of agricultural products globally. Tomatoes alone contribute nearly $2 billion annually to Dutch exports ($1.91 billion in 2020, according to Comtrade).

Innovative production approaches to increase crop yields have led to some of the most efficient farming methods globally. While the average global potato yield per hectare is about 9 tons, many Dutch farms produce over 20 tons. Rational water use for crop cultivation, based on Dutch methods, reduces water consumption by 90%. Large greenhouses in the Netherlands virtually eliminate the use of chemical pesticides. From 2003 to 2014, new production technologies increased vegetable yields by 28%, reduced energy consumption by 6%, and cut fertilizer use by 29%.

One way to enhance production efficiency in the Netherlands is by creating networks of large industrial greenhouses, some exceeding 70 hectares in size. These greenhouses not only maintain plants in warm environments, extending the growing season, but also enable precise measurement and control of growing conditions, such as soil moisture and optimal irrigation. Such efficiency has made the Netherlands the world’s largest exporter of tomatoes, a crop traditionally requiring a warmer climate.

Germany. Germany implements various pilot solutions, such as creating “digital fields” and forming expert groups under the Federal Ministry of Food and Agriculture, consisting of representatives from science and business. Particular attention is given to the development of digital infrastructure and providing rural areas with affordable broadband internet. In the ICT Development Index, Germany ranks 12th among 176 countries.

The use of modern digital information and communication technologies is one of the priority areas for the development of agriculture in Germany. Through the funding program "Land.Digital", the Federal Ministry of Food and Agriculture is driving digital transformation in rural areas by creating models and practical concepts under the Federal Rural Development Program. The government’s policy in the digitalization of agriculture focuses on finding stakeholders who aim to improve rural life through the intelligent use of information and communication technologies.

Agriculture in Germany includes both large and small farms, as well as part-time and full-time farmers. According to the Federal Ministry of Food and Agriculture, the following requirements must be met to expand the practical use of digital technologies:

- The digital infrastructure must be expanded and future-oriented (e.g., mobile broadband technology).
- Data flow between products from different manufacturers must be improved.
- Proper training and advisory services must be provided (farmers are not IT experts and require reliable information to make decisions about acquiring and using technology).
- The reliability of technology must be enhanced.
- Additional research into the benefits of digital farming should be conducted.
- Rules for data protection, data security, data sovereignty, and other conditions (e.g., air traffic regulations for the use of drones) must be established.

Since March 2020, the Federal Ministry of Food and Agriculture (BMEL) has been funding test "digital fields" on agricultural holdings to trial various digital technologies. Currently, there are 14 digital fields: eight in crop production, three in livestock farming, and three interdisciplinary test fields (including the use of the new 5G mobile broadband standard in agriculture). The Ministry has allocated over 50 million euros for the next three years.

Alongside digital test fields, the Federal Ministry of Food and Agriculture in Germany has created a new funding tool to tap into the potential of digitalization in agriculture. These test fields serve as digital testing grounds for determining the best ways to use digital technologies to protect the environment, improve animal welfare, support biodiversity, and reduce labor burdens. Startups can also participate in the project.

Poland. Poland's distinctive feature in its state policy for the digitalization of agriculture is simplifying bureaucratic procedures and increasing the efficiency of state service administration through the use of digital technologies. The country has implemented a "one-

stop shop" for farmers and has undertaken government support measures that indirectly contribute to improving the country's digital literacy. Poland ranks 24th out of 193 countries in the e-Government Development Index.

Currently, Poland has established a system of electronic interaction between the state and agricultural producers. The primary electronic services are provided by the Agency for Restructuring and Modernization of Agriculture (ARMA), which is overseen by the Ministry of Agriculture.

The Ministry of Agriculture and Rural Development, in collaboration with the Ministry of Digitalization, has taken its first step toward the digitalization of agriculture by creating an online service on the Gov.pl website. This service allows farmers to submit applications for assessing crop losses due to drought. This eliminates the need to appoint commissions, involve large numbers of people, and, importantly, ensures the uniform assessment of crop loss levels based on detailed data collected by the Institute of Soil Science and Plant Cultivation and the Institute of Agricultural and Food Economics.

This tool is continuously being improved. To this end, the Institute of Soil Science and Plant Cultivation uses radar data, which provides greater accuracy than data from ground-based weather stations. The launch of the "one-stop shop" has brought significant benefits, including reducing paperwork, saving time, and increasing efficiency.

Vietnam. With significant potential and advantages, aquaculture in Vietnam is actively developing. Recently, ministries, industries, localities, and the population have been actively promoting the application of digital technologies in aquaculture, thereby laying the groundwork for building and expanding e-commerce in the aquatic products sector. This has strengthened the connections among stakeholders within the value chain. The use of advanced technologies and the development of freshwater, brackish water, and marine aquaculture in a sustainable and environmentally friendly manner are being implemented in various regions.

For instance, in Quang Ninh province, the model of cage aquaculture in the sea, combined with the application of smart technologies for monitoring and controlling environmental factors such as temperature, dissolved oxygen, feed, and fish growth, has helped improve fish productivity, reduce mortality, enhance the efficient use of water and feed, and minimize environmental impact.

One of the key goals of Vietnam's future fisheries strategy is to optimize production management efficiency by promoting digital transformation. Digital transformation, leveraging modern equipment and information technology, aids in systematizing data on aquaculture areas, supporting product traceability, and managing the environment and diseases. This reduces labor costs, enhances the accuracy of management and monitoring, and boosts overall efficiency.

According to the Fisheries Department under the Ministry of Agriculture and Rural Development, in 2023, the area of aquaculture is estimated at 1.3 million hectares, with production reaching 9.269 million tons. The export turnover of aquatic products is estimated at approximately $9.2 billion. To date, the area of aquaculture certified by VietGAP is estimated at 13,000 hectares, with a projected output of 1.65 million tons.

Conclusions. Examining the stages of agricultural transformation highlights that, thanks to the development of IoT technologies, this process is rapidly advancing, supported by the emergence of local technologies and innovations. However, effective digitalization of agriculture requires addressing the following issues:

1. Digital Infrastructure: A lack of infrastructure limits the use of digital solutions in the field.
2. Internet Connectivity: Some areas lack internet access. Globally, this is being addressed through the deployment of low-orbit satellite constellations to reduce service costs.
3. Data Standardization: The absence of unified standards and regulations for data transfer and analysis using digital technologies and AI.
4. Testing Platforms: A shortage of technological testing grounds and experimental farms for piloting new technologies.
5. Skilled Workforce: A deficit of qualified personnel and the slow pace of reskilling specialists to meet emerging needs.

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