Information systems in organic agriculture: foreign experience

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Abstract. The article is devoted to the relevant topic of the application of information systems and technologies in organic agriculture. The authors substantiate the importance of using such systems to improve the efficiency and competitiveness of farms in the context of green economy development. There is a need to implement IT solutions to optimize business processes, accounting, data analysis, logistics, and sale of organic products. Based on the study of the positive experience of countries with developed organic production on the use of specialized information systems, it is concluded that the introduction of digital technologies, technologies involving automation of production, technological and management processes, will contribute to the long-term development of organic agribusiness, will produce better products with less harm to the environment, and will also increase the efficiency of organic production due to more economical use of resources. At the same time, the author points out a number of limitations: high cost of implementation, lack of qualified personnel among farmers, insufficiently developed infrastructure in rural areas. Nevertheless, the author sees the prospects for the development of organic agriculture in the creation of cloud solutions, integration with mobile technologies, the use of big data and artificial intelligence at all stages of the movement of products from the manufacturer to the consumer. In general, the article is of practical value, gives an idea of the current level and prospects of organic agriculture digitalization.

1 Introduction

In the context of green economy development, which involves the formation of such economic activities, infrastructure and assets that reduce carbon emissions and pollution, increase energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services [1] organic agribusiness fits perfectly into its main provisions and principles.

Organic agriculture, as defined by the International Federation of Organic Agricultural Movement (IFOAM), is a production system that supports the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity, and cycles adapted to local conditions, rather than on the use of resources with adverse consequences. Organic
agriculture combines tradition, innovation, and science to benefit the common environment and promote fair relations and a good quality of life for all participants [2].

The spread of digital technologies involving efficient resource conservation opens up new opportunities for organic agribusiness, allowing environmental groups to reduce the impact of agribusiness on the environment [3]. Digital technologies are aimed at improving the efficiency of food production, solving environmental problems and increasing consumer confidence in agri-food systems. The integration of innovative developments in the field of data processing and telecommunications with the already existing idea of precision agriculture is the basis for the formation of intelligent agriculture, which is often associated with organic production, especially when it comes to industrial scale.

2 Research methods

The work is based on the study of domestic and foreign scientific literature, as well as Internet sources describing the experience of using various information systems and technological solutions for the production of organic products, as well as state policy and regulatory framework for the regulation of organic production and digital transformation of agriculture. The subsequent generalization of the information received will make it possible to justify the introduction of digital technologies in the expansion of organic production in Russia in the context of green economy development [4].

3 Results and Discussion

According to the latest data of 2021, the market of organic products has reached almost 125 billion euro ($170 billion), which is 4 billion euro higher than in 2020 (3%). The leading global market is the United States (48.6 billion euro), followed by Germany (15.9 billion euros) and France (12.7 billion euros). In 2021, 3.7 million organic producers from 191 countries were registered, which is 4.9% more than in 2020 [5]. At the same time, India remained the country with the largest number of organic producers (1.6 million). Despite the slowdown in the growth of organic production worldwide, many countries continued to implement policies to support organic agriculture and stimulate its development [2].

Considering the specifics of the production of environmentally friendly products to meet the global demand for organic agricultural products, the main direction of its development is the introduction of innovative methods and technologies into the production process. While consumer demand for organic agricultural products is growing, organic farming companies around the world are trying to keep up with changing trends and stricter certification rules. The use of information systems in organic agriculture is conditioned by the need to increase its efficiency and manageability, improve product quality and comply with the requirements of organic farming standards in green economy. They allow to automate many routine processes and make more informed management decisions.

The scheme of interaction of information technologies in the production of organic products is shown in Figure 1.
Fig. 1. The sequence of the use of information technologies in the production of organic products.

All these elements interact together to create information systems that help farmers to optimize their activities, increase crop yields, animal productivity and, in general, ensure an increase in the efficiency of organic production.

There are certain types of information systems that are widely used in organic agriculture.

1. **Information technologies in business process management.** Information systems that help manage all processes at the enterprise - from production to logistics and finance - allow you to control raw materials, track the entire life cycle of a product, consider inventory and orders, and control expenses and incomes of the enterprise.

Since organic farming requires a unique crop management system, different from that used in traditional agriculture, the introduction of ERP and CRM systems makes it possible to increase the efficiency of the overall management of farming, material and financial resources. For example, FarmERP, popular in more than 25 countries, including India, presents a new way of using farm management technology and data management tools for organic farming and includes the following:

- systems for accounting and analysis of yields of various crops, including in dynamics;
- systems for planning crops, considering crop rotations and mutual location of crops;
- land monitoring systems for monitoring the state of the soil and its main characteristics;
- agronomic systems, including data on recommendations for the care of various crops, optimal timing of sowing and agrotechnical work;
- systems for monitoring the movement, condition, and serviceability of machinery and equipment;
- cost accounting systems for the main types of material resources (seeds, fertilizers, fuel, etc.).

In the USA, one of the most popular systems for crop assessment, management and cost planning is FarmLogs, which is used by many farmers engaged in organic agriculture. The information system helps to accurately measure the yield in the context of fields and crops, analyze data in dynamics, and calculate the expected profit. FarmLogs allows to keep records of all costs associated with organic production (fertilizers, seeds, labor, fuel, etc.), monitor the state of the soil (pH, humidity, nutrient levels), and then, based on the collected data, makes recommendations based on successful agrotechnical practices compatible with organic farming, considering natural and climatic conditions and weather conditions, as well as crop features. The use of the system involves integration with other systems (ERP, tax calculations, etc.)

One of the world's largest ERP systems - SAP ERP, allows to fully cover and automate all business processes of organic production, plan agricultural tasks and resources. Designed for large companies. It allows to increase the efficiency and sustainability of agriculture by digitizing agricultural processes and services and providing data-based management of agricultural operations. Thanks to the capabilities of data processing and machine learning, it allows to switch to intelligent agriculture, optimize business processes from planning to harvesting based on the use of structured and unstructured data from various sources.

Another popular FarmOS information system helps farmers manage the process of organic farming, which requires crop rotation and the application of certain fertilizers to maintain soil health. It includes crop planning and crop rotation, weather monitoring, financial accounting, nutrient management, application of mineral and organic fertilizers, pest control organization, useful documentation for compliance with organic farming standards. FarmOS can also be integrated with other organic farming management systems.

In addition, for enterprises engaged in organic production, it is possible to use information systems for managing processes and resources of a wide profile. For example, Microsoft Dynamics NAV, a popular system in the USA, includes solutions for inventory accounting, product tracking and quality control and meets the requirements of organic production. Oracle E-Business Suite is a powerful and functionally rich ERP that allows full control of organic ingredients and production processes.

2. **Information systems for compliance with organic production standards.**

Information systems can help farmers comply with the requirements of organic farming standards, including the production, labeling, and certification of organic products, as well as requirements for ecological and socially sustainable farming. In addition, digital solutions allow to track operations and provide the documentation necessary for certification and verification of compliance with standards.

The certified database containing detailed information about organic standards and certification in the USA Organic Integrity Database is an analytical panel of the USDA Organic Integrity database and analytical tools for the National Organic Certification Program. It helps farmers to track compliance with requirements, as well as the movement of organic products along the entire chain from producer to buyer [6]. In addition, the analytical panel searches for certified organic farms, businesses, or enterprises with certain characteristics, such as:
- status of the enterprise, producer of organic products (certified, certification documents, certificate revoked or suspended);
- type of certified products: agricultural crops, livestock, wild crops, or processing of products.

In Switzerland, organic agriculture plays an important role in providing the population with food: the market share of organic products in 2022 was about 11.2%, and the number of farms is 7,560 and continues to grow. BioSuisse is a Swiss organic agriculture association that ensures market transparency and promotes fair pricing policy throughout the value chain. BioSuisse has an online platform for farmers with information about standards and certification procedures, information about organic farming (from production to marketing), animal husbandry, market, etc., the most important links for organic producers and for those who would like to become them.

OrganicXseeds is an Irish information platform for farmers with a database on organic seeds, vegetative materials for reproduction and seed potato. The website is also intended for use by certification bodies and seed companies wishing to sell certified organic seeds.

3. **Information systems for monitoring and risk management.** Information systems can help farmers monitor and manage risks related to climate change, plant and animal diseases, as well as collecting data on soil and water quality. This can help farmers prevent crop losses and improve product quality.

Information systems for monitoring and risk management in organic agriculture may include the following components:
- meteorological stations that allow to receive information about current weather conditions;
- automated irrigation systems will reduce the risks associated with a lack or excess of moisture;
- information systems for plant disease management and containing recommendations on the use of organic methods of disease control and prevention of their spread;
- market analytical systems will help farmers in making decisions about resource allocation and preventing risks associated with market fluctuations.

All these information systems can be integrated into a single platform that allows farmers to receive and analyze risk data, predict their occurrence and make strategic decisions to manage these risks in organic agriculture, which will allow farmers to reduce potential losses and ensure more stable and sustainable agricultural production.

Widespread (covering more than 50 countries) American Cropio information system allows remote monitoring of the state of agricultural land, acreage, and harvest, automatic documentation, forecasting and planning of agricultural operations. Cropio integrates with 1C, GPS transport monitoring systems, weather stations, drones from different manufacturers, various sensors, and controllers. Mobile applications are available for Android, iPhone, iPad users for various purposes: tracking the yield forecast and the progress of harvesting campaign, harvest control, satellite monitoring and detailed reports on field inspections. It helps to minimize risks in organic farming.

Agrivi is a farm management software developed in Croatia and popular in Eastern Europe. The management system expands the capabilities of producers and the value chain in the agri-food organic sector with the help of real-time analytical data, includes risk analysis modules for conversion to organic production.

4. **Information systems that allow to keep statistical records and analyze big data.** Systematic collection of data on all aspects of production using precision farming systems using GPS, sensors in fields, machinery, warehouses; satellite images; animal monitoring systems with sensors to track health, movement, physiological parameters forms a huge array of unstructured data that contains important information that helps make informed decisions to optimize production processes.
A good example of such an information system is AgSquared (USA), a cloud service for collecting and analyzing data on a farm. It allows to keep records of yields, sales, expenses in organic production. AgSquared is a comprehensive software platform that is completely based on cloud technologies, allowing to coordinate the work of managers, agronomists, tractor drivers, and foremen at any time and anywhere, providing access to the information they need to make informed decisions that will help improve the productivity, profitability, sustainability, and efficiency of agribusiness. AgSquared has a mobile version for each team member, which allows to quickly and efficiently enter indicators at each stage of production and monitor the state of the enterprise in real time. Reports and dashboards combine data on all activities to help to visualize key performance indicators, maintain and issue all necessary documentation, make informed decisions and document compliance with organic production requirements.

Agroptima (France) is an online platform for accounting and reporting on the farm. It has functionality for statistical analysis in the context of organic and traditional production. The online platform allows not only to manage agricultural work, recording the entire production process in real time, using a database of phytosanitary products, seeds, fertilizers to purchase the necessary materials, but also promptly generates a field log with the main indicators and generates reports on the introduced preparations. In addition, there is a cost tracking and revenue generation function.

Agrimetrics (UK) is a system for collecting and analyzing agricultural data. Provides tools for statistical accounting in the organic sector. The Agrimetrics data market combines data on organizations in the food and agriculture industries to create a more productive and sustainable food system.

Since the agri-food sector is one of the least digitized industries in the world, where there are serious obstacles to the collection, exchange and use of data, the Agrimetrics data market is a Data Marketplace for data exchange between farmers for further collaboration. Artificial intelligence helps to combine disparate sets of agricultural and environmental data in the market, quickly and economically provide ready-to-analyze data to interested users, which makes the accounting process more transparent and efficient.

5. **Information systems for monitoring the state of the soil, as the most important production factor.** Information about the fertility and quality of the soil allows to select the most productive crops, as well as cultivation methods suitable for specific soil conditions. Digital technologies make it possible to improve the productivity and sustainability of agricultural systems, while maintaining the organic nature of the economy, and their use in soil monitoring will allow farmers:
- to improve control over the content of nutrients in the soil (nitrogen, phosphorus, etc.), which allows farmers to more accurately dose fertilizers, reduce their consumption;
- to increase productivity and product quality;
- to increase the stability of the soil ecosystem, since healthy organic soils are more resistant to droughts and diseases;
- to identify and respond to soil health problems faster, which will reduce the risks of serious crop losses;
- to follow strictly the standards of organic farming.

There are a lot of examples of using digital solutions that monitor soil: Agronomix, a Canadian company that offers digital agronomic solutions for farmers with organic crops, SmartFarm from Australia offers a soil monitoring and irrigation management system. With the help of sensors and data collection, they can provide information about the nutrient content and soil moisture, which makes it possible to optimize the use of fertilizers and water, etc. In general, digital soil monitoring systems can measure organic carbon levels, pH, humidity and other parameters that show the soil health.
6. **Information systems for monitoring the plant condition.** In organic agriculture, it is especially important to monitor the condition of plants to ensure their healthy growth and yield. For this purpose, information systems are used that allow monitoring of various plant parameters to control and optimize processes in organic agriculture.

One of the main information systems used in organic agriculture is a system for monitoring and controlling soil moisture. The system allows using sensors to measure soil moisture and give recommendations for irrigation.

Another important information system is related to the tracking of nutrients in the soil. Organic agriculture strives for sustainable and efficient use of nutrients, therefore, a system for monitoring the content of nitrogen, phosphorus, potassium, and other elements in the soil is necessary. With the help of sensors installed on the plots, the information system monitors the level of nutrients and recommends the necessary doses of organic fertilizers.

Also in organic agriculture, information systems are used to control pests and plant diseases. With the help of sensors including infrared cameras or pest detectors, the system can detect insects or diseases early and warn about their appearance. This makes it possible to take timely measures to combat pests and diseases, minimizing the use of pesticides.

All data received from sensors and detectors in organic farming is collected and processed by information systems. The monitoring results are transmitted to the computers or mobile devices of farmers, who can make decisions based on this data. This makes it possible to optimize processes in organic agriculture, increasing productivity and product quality.

Plantix is a German technology that uses artificial intelligence to analyze photos of plants. The system can identify problems such as moisture or nutrient deficiencies, as well as infections and pests. At the same time, diagnostics is carried out on more than 30 agricultural crops, detects more than 608 diseases using machine learning and artificial intelligence. The undeniable application advantage is its free use in 18 languages.

CropWatch is an American company offering a system for monitoring plant growth and health using sensors and cameras. This allows farmers to monitor moisture levels, nutrients, and plant health.

Farmers Edge from Canada offers a powerful integrated digital farming platform that includes plant health monitoring using sensors and satellite images, which helps farmers optimize plant care.

Many universities and research centers around the world are working on developing technical solutions that allow to assess the health of plants, while considering the peculiarities of growing regions and cultivation technologies. In general, such systems help farmers to detect plant stress or nutrient deficiencies at an early stage to make adjustments to farming in time. This has a positive effect on the yield and quality of products in organic agriculture.

7. **Information systems for monitoring the condition of animals.** There is a wide variety of information systems that are used to track the condition of animals in organic agriculture, which include the following:

- Radio frequency identification (RFID) systems use microchips embedded in animals to track their movement and basic health indicators (body temperature, pulse, and activity). This helps farmers to monitor each animal, control its reproduction and diseases;
- animal morbidity tracking systems for tracking diseases and the spread of infections among animals. They include disease databases and data analysis tools. Such systems allow farmers to take measures to prevent the spread of diseases;
- feeding control systems help to ensure rational nutrition and feed consumption volume. They can also be used to control feed allowances and additives to ensure compliance with organic farming standards;
- systems for monitoring physiological indicators of hormone levels, pheromones, body heat and other physiological parameters, which helps to determine the optimal breeding period and the general condition of animals;
The considered information systems help farmers to minimize environmental impacts and ensure compliance with organic farming standards.

There are many information systems for tracking the condition of animals on farms, considering the size of farms, specialization, types of animals, etc. An example of the use of information systems in animal husbandry is FarmOS (USA). The farm management system is a web application and includes functions for tracking the condition of animals through various sensors and devices, such as six animals constantly monitors the location and activity of animals, as well as the level of their stabilization. In Europe, the platform is used in organic agriculture.

Allflex Livestock Intelligence is a global leader in the design, development, production, and supply of solutions for animal identification, monitoring, farm management, and tracking. It provides unique tools, information and services based on data on more than 500 million animals, which allows farmers to provide more accurate nutrition recommendations, genetic health management strategies, etc., while reducing the time on the farm.

In Russia, a multi-profile M2 farm has also been founded specifically for the organic production of agricultural products in the Ruza district of the Moscow region, in which IT technologies are actively used. Specially for the organic farm, software was developed - the mobile solution "Reader Farm M2", special RFID tags and readers are used, capable of receiving all the basic information about the animal, on the basis of which the number of livestock, sexual hunting and pregnancy period, weight gain trend, vaccination history, and medication intake are monitored in real time, as well as remote accounting of animal transportation. Dairy cows are additionally provided with special tags for robot milkers that identify cows for admission to the milking area. The program also tracks the productivity of farm workers [7].

8. Information systems that allow communication. Information systems can help improve communication between farmers, consumers and other stakeholders, which will make relations between organic market participants more trusting and transparent.

For example, in the USA, the LocalHarvest website is popular, where farmers, including organic producers, can post information about their products and sell it directly to the consumer without intermediaries, negotiate with other producers on joint promotions. The site actively supports organic producers, encouraging consumers to make a choice in favor of environmentally friendly products. Thereby maintaining a healthy environment and ensuring the sustainability of the ecosystem. In the USA, in addition to LocalHarvest, the FarmersWeb farmers' communication site is popular, where farmers can join communities in areas (animal husbandry, crop production, etc.), share information and experience. There are also sections of ads and vacancies.

One of the most recently developed digital tools that significantly improves communication between farmers in Italy is FarmSuite. This initiative is an integrated, easy-to-use modular platform designed for small and medium-sized organic farms and processors, with the aim of allowing farmers to save time and reduce costs. On the one hand, it is a modular management tool for farmers, including the tools necessary for effective planning, management, and optimization of production and sales. On the other hand, it gives each farm access to a virtual farmer's market, which can be used to tell the story of the farm and sell products directly to consumers.

The following information systems are popular in Europe to help improve farmers' communication in organic agriculture:

1. Platforms for the sale of products. These are mainly websites and mobile applications where farmers can post information about their products and find buyers. Examples of such systems: FranceAgriMer, Freshplaza, BioDB (Sweden), etc.
2. Virtual fairs and markets. Online exhibitions and markets are organized where farmers can exchange information, find partners, and conclude deals: AgroVirtual (Spain), Virtual Agrarian Fair (Portugal).

3. Social networks for farmers. They allow farmers to quickly exchange information about high-quality production, discuss problems and find a community of like-minded people.

4 Conclusions

Every day the use of the Internet and smartphones is growing rapidly, and with them the possibilities of using intelligent technologies, using cloud services for big data analysis, mobile applications and integrated platforms are expanding. This is the main trend in modern agriculture, which will increase labor productivity and production sustainability, provide support for decision-making and, ultimately, contribute to providing food to the growing population in the world [8]. Especially relevant is the use of digital technologies by organic producers, who have a number of restrictions on agrotechnical methods of cultivation of crops and zootechnical features of animal rearing.

According to some researchers, organic producers are more active users of digital technologies and innovative solutions for agribusiness, benefit from more sources of information than ordinary producers. In addition, they are more actively exchanging information and technologies, using modern digital platforms to promote organic products [9]. Thus, organic agriculture is the most important direction in the development of green economy.

In modern conditions of digital transformation of the agricultural sector, many technological solutions for organic production are presented on the market of information systems and technologies. Depending on the specifics, requirements, and scale of the business, you can choose the most suitable digital products, the main advantage of which is full transparency of business processes from the manufacturer to the consumer.

An important problem limiting the use of information systems in organic agriculture both in Russia and in the world is the high cost of technological solutions along the entire food supply chain, as well as the lack of qualified personnel, managers and specialists in the field of eco-production [10, 11, 12]. For example, according to the Union of Organic Agriculture, the costs required for the introduction of information technologies are estimated at $ 200-1000 per 1 ha for cereals and $5000-8000 per 1 ha for fruit cultivation [13], which hinders the development of organic agriculture.

Nevertheless, the formation of agro-food systems functioning on green economy principles is a prerequisite for the conservation of resources for future generations, therefore, despite the difficulties, it is necessary to make a number of efforts on the part of the state to stimulate and financially support the transition to a fair, environmentally oriented, healthy system of organic agriculture.

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