DOI: 10.15276/ETR.01.2021.9
DOI: 10.5281/zenodo.4885364
UDC: 338.43:004
JEL: Q16

DIGITALIZATION OF THE AGRICULTURAL SPHERE: STATE, PROBLEMS AND PROSPECTS

ДІДЖИТАЛІЗАЦІЯ АГРАРНОЇ СФЕРИ: СТАН, ПРОБЛЕМИ ТА ПЕРСПЕКТИВИ

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Received 05.02.2021

Лігоненко Л.О., Ланова О.Л. Діджиталізація аграрної сфери: стан, проблеми та перспективи. Оглядова стаття.

В статті аргументована актуальність діджиталізації аграрного сектору в Україні . Проаналізовані діджитал-технології в аграрній сфері на основі класифікації за їх функціональним призначенням. Охарактеризовано кожен з етапів діджитал циклу: збір даних, аналіз даних, зберігання даних, управління даними, передача та спільне користування даними. Висвітлені існуючі проблеми оцінювання поточного стану діджиталізації аграрної сфери України та здійснено аналіз наявної інформації, яка характеризує поточний стан справ. Розглянуто приклад успішного впровадження діджитал процесів на підприємстві Kernel, який наочно вказує на те, що завдяки діджитал технологіям бізнес-процеси аграрних підприємств можуть докорінно змінитися, підвищуючи ефективність його бізнес-діяльності та забезпечуючи конкурентоспроможність та успішність розвитку.

Ключові слова: аграрна сфера, агробізнес, діджитал технології, діджиталізація, цифрове сільське господарство, краудсорсинг, блокчейн

Ligonenko L.O., Lanova O.L. Digitalization of the agricultural sphere: state, problems and prospects. Review article.

The article argues the relevance of digitalization of the agricultural sector in Ukraine. Digital technologies in the agricultural sector are analyzed on the basis of classification according to their functional purpose. Each of the stages of the digital cycle is described: data collection, data analysis, data storage, data management, data transmission, and sharing. The existing problems of assessing the current state of digitalization of the agricultural sector of Ukraine are highlighted and the analysis of available information characterizing the current state of affairs is carried out. An example of successful implementation of digital processes at Kernel is considered, which clearly indicates that due to digital technologies, the business processes of agricultural enterprises can change radically, increasing the efficiency of its business activities and ensuring competitiveness and development success.

Keywords: agrarian sphere, agribusiness, digital technologies, digitalization, digital agriculture, crowdsourcing, blockchain

Digital technologies have long been recognized as a key factor in reducing the digital divide and achieving three dimensions of sustainable development: economic growth, environmental balance, and social integration. They have proven their effectiveness in health, education, finance, and trade by providing information and services, as well as promoting greater transparency and accountability. Using information and communication technology (ICT) solutions, problems that have been a burden on the agricultural sector for too long can be solved. However, in order to effectively use the potential of digitalization in the agricultural sector, it is necessary, on the one hand, to systematize theoretical developments on this issue, and secondly, to understand the current state of affairs and the best examples of digital technologies in the agricultural sector industry.

The agricultural sector remains one of the main sectors of the Ukrainian economy. During the period 2016-2017, it amounted to 10-12% of the GDP (nominal) of Ukraine, entering one of the largest industries in the country. About 17% of the working population is employed in agriculture.

The importance of the agricultural sector is confirmed by the constant growth of foreign trade. During 2010-2017, the share of agricultural products in total exports increased from 21% to 44%, respectively [1]. According to the Ministry for Development of Economy, Trade and Agriculture of Ukraine [2, 3], exports of goods from Ukraine amounted to 50.1 billion dollars in 2019.

Products of the agro-industrial complex (AIC) and food industry traditionally occupy the first place in the structure of goods export. Its volume increased to 22.1 billion dollars. (an increase of 19% compared to 2018), i.e. 44.2% of total exports. In 2019, the largest growth occurred in the category of cereals – by 33% (by $ 2.4 billion) and seeds and fruits of oilseeds – by

31.2% ($ 609.1 million).

According to [4], the agricultural sector of Ukraine is dominated by large farms and agricultural holdings, of which 70 agricultural enterprises are engaged in growing monocultures. In addition to large enterprises, more than 900,000 unregistered small or family farms are engaged in agricultural production and produce products for local markets, creating most employment opportunities in rural areas.

Thus, the digitalization of agriculture is relevant and extremely important for the country as a whole (contribution to the GDP and export potential, employment of the rural population, promoting the goals of the United Nations Sustainable Development – combating poverty and inequality, food security, positive impact on ecology, etc.), as well as it is a tool for improving the efficiency of management, ensuring the current and future competitiveness of a large number of agricultural businesses.

Analysis of recent research and publications

Increasingly, the issue of digitalization is covered in the research of foreign scientists, in particular G. Valenduc, G. Vial, P. Parviainen, G. Myovella, and others. Despite the fact that digitalization in the West is developing faster Ukrainian scientists do not stay away from this topic. Studies of digitalization are covered in the works of such scientists as O. Gudz, O. Grybinenko, M. Dubyna, L. Lazebnyk, and others. Systematization and critical review of research on digitalization are presented in [5-12].

The issue of digitalization of agribusiness is still insufficiently covered. Only the work of scientists of Zhytomyr National Agroecological University [13] is directly devoted to the agrarian sphere, which considers the sources and financial mechanism of support for these processes, as well as structured the mechanism of introduction of digital technologies in agribusiness.

Given the relative novelty of the concept of "digitalization" and the lack of scientific research, this topic requires further in-depth scientific study.

Unsolved aspects of the problem

The aim of the article is to systematize possible directions (spheres) of digitalization of agriculture, study the features of digital technologies in agriculture, characterize the possible effects and consequences of digitalization of the agrarian sphere, as well as highlight the problems and results of assessing the current state of digitalization of Ukrainian agricultural enterprises.

The main part

Early waves of technological progress in agriculture introduced mechanization, more productive and more stable varieties of seeds, as well as agriculture with the introduction of satellite GPS for the management of agricultural machinery. Based on these past achievements, the current wave of technological progress focuses on the creation, use, consolidation, analysis, and sharing of agricultural and other data in digital format to increase the sustainability and productivity of agriculture and food systems.

According to the Food and Agriculture Organization of the United Nations, digital agriculture is the planning, development, and application of innovative ways of using information and communication technologies (ICT) in rural areas, with a focus on agriculture and food, including fisheries, forestry, and livestock [14].

The report "Digital Opportunities for Improving Agricultural Policy" [15] identified the cycle of digital technologies and its most important components (Fig. 1).

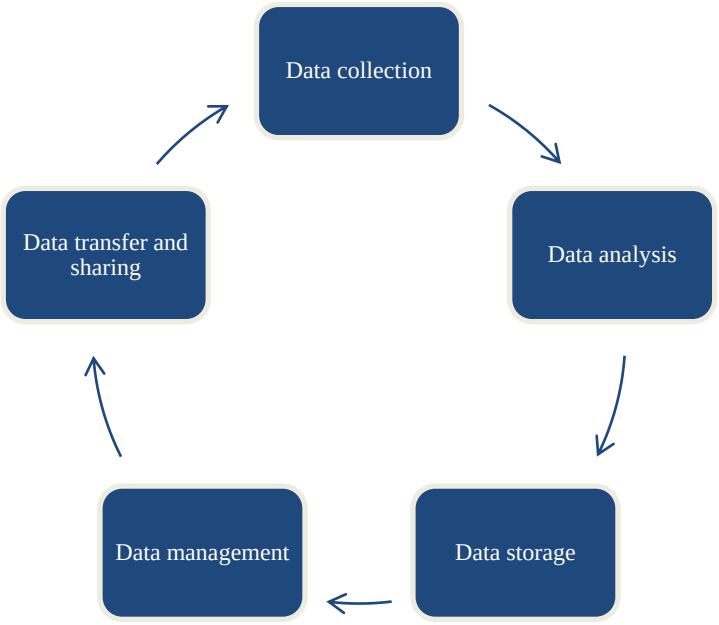

Figure 1. Cycle of digital technologies in agriculture
Source: compiled by the author on the materials [15].

Based on [15], it is possible to determine the priority areas and directions of digitalization in agriculture grouped according to their functional purpose (table 1).

Table 1. Digital technologies for agriculture

Sphere (direction) of digitalization	Digitization tools
Data collection	Remote sensing
	On-site sensing
	Gathering information through crowdsourcing
	Online surveys
	Collection of financial or market data
Data analysis	Analytical tools based on geographic information systems
	Crowdsourcing data analysis
	Artificial Intelligence
Data storage	Secure and accessible data storage
Data management	Data management
Data transfer and sharing	Digital communication technologies
	Online platforms

Source: compiled by the author on the materials [15].

Let's consider in more detail each selected component of the digital cycle, based on the results of research and conclusions given in [1-5, 14-15]:

Stage 1 – data collection. Basic data collection in digital agriculture should take place through remote sensing and on-site sensing. In the first case, it is automated using sensor technologies such as drones (manned aircraft can also be used) and satellites, or in the second case, it can be done manually by a human observer.

Significant progress has recently been made in the use of satellite remote sensing to obtain more accurate data in agriculture. Problems in crops can be identified remotely before they can be identified visually. Remote sensing images can be used to detect nutrient deficiencies, to detect disease, water deficiency or excess, pest and weed infection, insect damage, hail, or wind.

This information is valuable because it is used as a basis for the application of fertilizers and pesticides at a variable rate. Information from images obtained by remote sensing allows farmers to cultivate only the affected areas of the field.

Gathering information through crowdsourcing promotes public involvement and participation in science and innovation. Currently, there are publicly available applications that seek to engage the efforts of citizens to collect or process data. These apps should include elements of gamification (ie adding gameplay elements to existing apps) to help motivate "volunteers". In the agricultural context, such applications have so far been used mainly for land use monitoring and land classification, but their scope can be much wider.

Stage 2 – data analysis. The use of analytical tools based on data analysis of geographic information systems is useful in modeling (watersheds, topography) and mapping (land cover), which, in turn, can be used in forecasting crop yields.

Digital technologies can leverage the accumulated knowledge of groups of people and expand access to information, finance, and markets through crowdsourcing. Basically, this digital tool helps with gathering information, but it can also be used for analysis. For example, as noted in [16]. Plantwise is an initiative that offers farmers tools to diagnose crops and pests. Plantwise collects information from farmers on soil health and other risk factors, which transmits data from their fields to a central Plantwise database. This database is then analyzed by its employees. In exchange for participation, farmers receive technical assistance via SMS and voice messages on how to get rid of or avoid pests, thereby reducing crop losses.

In [17] there are four main categories of application of artificial intelligence in agriculture:

— image recognition and perception – the versatility and modern technologies for visualizing the results of unmanned aerial vehicles make them popular for field research;
— skills and manpower - artificial intelligence allows farmers not only to collect large amounts of data from the government as well as public websites but also to analyze them and provide farmers with solutions to many ambiguous issues, as well as recommend a smarter irrigation method that leads to higher yields agricultural land;
— crop maximization – new technologies have helped to select the best assortment of crop seeds that are suitable for the needs of a particular farmer. This is accomplished by understanding how seeds respond to different weather conditions, different soil types. Analyzing this information, the chances of plant diseases are reduced;
— chatbots are conversational virtual assistants that automate interaction with end-users in a personalized way. In the agricultural sector, they help farmers get answers to their questions by giving them advice.

Stage 3 – data storage. As the amount of information is constantly growing, the agricultural enterprise needs a reliable and easily accessible way to store data.

According to [18], cloud services can increase flexibility, reduce infrastructure requirements,

optimize processes, improve accessibility, and efficiently handle large data sets.

Cloud-based software (SaaS) is expected to be the market leader in farm management software of the future. When using the software, users only need to access the records provided by the vendors through their appropriate web browsers.

Stage 4 – data management, which is provided by distributed registry technology, namely – blockchain. According to the research [19], blockchain is widely used in such areas as agricultural insurance, land registration, supply chains, etc. For example, by increasing the transparency of agricultural supply chains, a blockchain can help ensure product tracking from the point of origin to the retail store. This can increase consumer confidence in the goods they buy, as well as reward producers who use advanced farming methods to grow their products. Ultimately, this can lead to responsible consumption, food safety, as well as reducing the number of food fraud cases and enhancing the brand's reputation.

Stage 5 – data transfer and sharing. This area of digitalization includes technologies that actually use the transfer or sharing of data to facilitate other types of transactions, such as ownership, communication (between people or digital devices), and digitally delivered services.

In the research [20] it was proved that the factors influencing the tendency to exchange data of agricultural holdings were the age of the farmer and the use of irrigation. Older farmers are less likely to share their data than younger farmers, most likely because the older generation is more skeptical and less knowledgeable about new technologies. Also, producers who do not use irrigation are less likely to share their data, which could be due to their lower production intensity. Farmers with more technical skills, namely those who use a cell phone with Internet access and more digital agricultural technology in their work, were less likely to share their data, perhaps because of their better understanding of agricultural issues, which allows them to solve them on their own.

Thus, the areas and opportunities for digitalization in agriculture are extremely diverse and multifaceted.

What is the current state of Ukrainian agriculture digitalization? Which of the above has already been adopted by Ukrainian farmers who are in the process of mastering? These questions remain unanswered at present.

As you know, the only source of information about the implementation of ICT is the form 1-ICT "Use of information and communication technologies in enterprises", which is compiled in the form of a survey with the preferred answer "yes" or "no". Issues of this form relate to the use of computer networks, the Internet, social media, cloud computing, "big data", 3D printing, e-commerce, the presence (absence) of ICT specialists in the enterprise. The official website of the State Statistics Service of Ukraine presents summary data on the use of information and communication technologies (ICT) in Ukrainian enterprises in terms of economic activities [21], but according to the methodology of this state statistical survey [22], which was developed in accordance with the Regulations EU № 808/2004, agriculture, is not the subject of the study. Therefore, it is currently impossible to analyze the state of digitalization of the agricultural sector of Ukraine on the basis of the use of statistics observations.

We have a similar situation with the European Union. The official Eurostat website [23] reflects a fairly wide range of information, broader and more interesting, including general information on ICT systems, Internet access and use (including mobile Internet use), e-commerce, e-business (cloud computing, software provision as a service, Internet of Things, big data analysis, 3D printing, robotics, artificial intelligence, etc.), ICT specialists, ICT, and e-skills training, ICT security. However, well-established statistical observation, for reasons we do not understand, also ignores agriculture. Given the role and importance of agriculture for most EU countries and its food security, a gap in the methodology of statistical observations has been identified. EU Regulation № 808/2004 needs to be urgently corrected by expanding the list of areas (activities) for which relevant information is collected, in particular the inclusion of companies operating in the agricultural sector.

Despite the lack of systematic information (based on systematically organized statistical observations), certain conclusions about the state of digitalization of both Ukrainian and European farmers can be made on the basis of information from special studies conducted in this area.

Experts from the Food and Agriculture Organization of the United Nations have developed a regional index eAgri [14], which assesses the need and readiness of Europe and Central Asia to develop and implement digitalization strategies in agriculture. This index is calculated on the basis of 90 evaluation indicators, which are structured as follows:

— indicators that characterize the situation with the implementation of ICT: the percentage of Internet users; the percentage of the population covered by 3G and LTE / WiMAX mobile networks; active mobile-broadband subscriptions per 100 inhabitants; the estimated proportion of households with Internet access at home;
— indicators that characterize the existence of favorable conditions for the development of ICT: the availability of latest technologies; government success in ICT promotion; the importance of ICTs to government vision; ICT use and government efficiency; laws relating to ICTs;
— macroeconomic indicators related to agriculture: the percentage of agriculture from GDP; the percentage of employment in agriculture; value-added per worker in agriculture; total Factor Productivity growth.

The leaders of the eAgri index are such countries as Luxembourg, Norway, Estonia, Iceland, and Sweden, which take 1-5 places respectively. Ukraine ranked 47th (out of 49 countries surveyed) in the development of digital agriculture. Uzbekistan ranks

46th in this index, closes the ranking (48-49 place) – Bosnia and Herzegovina and Kyrgyzstan, respectively.

According to [24], about 10% of Ukrainian agricultural companies take advantage of digitalization, which is an extremely insufficient level.

Currently, in Ukraine at different stages of their development, there are about 70 startups that have proposed and implemented perspective digital solutions and technologies, namely: solutions for farm management (hardware developers, software developers), solutions for precision agriculture (equipment developers), solutions based on drones and remote sensing (hardware developers, software developers), as well as urban agricultural startups [24].

A vivid example of digitalization of business processes can be such agricultural enterprises as Kernel, AgriChain, Syngenta, and Ukrlandfarming, which were included in the ranking of TOP-25 leaders of Ukraine digitalization according to [25].

Consider in more detail the state of digitalization of economic activity of the leader of Ukrainian digitalization - the agricultural holding Kernel.

Based on [25-26], it can be argued that Kernel uses digital technology on all defined in Fig. 1 stages of the digital cycle. The company has created a digital ecosystem, DigitalAgriBusiness, to consolidate all agricultural production processes. The reason for this was the scale of the enterprise, namely the complexity of managing the largest land bank in Ukraine, so digitalization has become necessary for further quality decisions.

In [26, 27] Kernel's achievements, results, and plans for digitalization are covered in detail. In generalized form, they are as follows:

— 100% of the fields are covered with high-quality RTK signals (measurement error – no more than 2 cm), which are the basis for digital agriculture. Ukrainian business organizations share data from RTK signals, thus ensuring absolute coverage of areas;
— 100% of the fields are covered by meteorological monitoring. The company uses its own database of weather stations, as well as organizes joint projects with other business organizations to expand the database;
— 100% of the fields are controlled by satellite images, quadcopters (drones), as well as IT tools with which agronomists work directly in the fields. The data of this monitoring is automatically stored in the database. Then this information becomes the basis for the GIS portal. GIS-portal – an analytical resource for easy evaluation and comparison of fields taking into account their geographical location, compliance with technology, etc. With the help of the Internet you can go to any field from anywhere in the world, see all possible reports and analytics, videos, and photos;
— the work of agronomists has changed radically: there is no need to be constantly present in the field. All business processes are integrated into mobile applications for each agronomist. "Mobile agronomist" (MAG) is a project of process standardization by means of which algorithms of work, an estimation of a condition of crops, detection of risks and harmful objects will be identical for all employees of the enterprise;
— a unique algorithm for yield forecasting based on the analysis of satellite monitoring results has been developed. The forecast of gross grain production, construction of high-quality logistics, and sales management under forwarding contracts – all this can be obtained with high accuracy due to the algorithm. In 2018, this project was tested in all fields of the company and proved its effectiveness;
— a complete abandonment of paper media is planned, instead – automation of accounting of inventory through mobile devices. The company can already use the Telegram-bot, through which you can agree on a document without entering the site and the mobile use of electronic signatures in full compliance with the law. All this information has the necessary protection system. All this makes it possible with the help of an electronic document management system to transform business processes, rather than simply automating and translating paper documents into electronic form;
— in the work of the control center introduced data processing tools using Big Data technology (online mode), which allows you to automatically constantly monitor events by the control center;
— digital technologies are used in factories, terminals, and elevators, used in the processes of acceptance, processing, transshipment. For example, in order to increase the speed of reception in the elevator and facilitate the movement of vehicles in the elevator, the driver, approaching the elevator, gets in the electronic queue and at the right time receives a message on the phone or sees his number on the board. The weight of the product is determined automatically, without human intervention. All these data are entered into a single system: they are integrated with each other and exchange information in real-time.

Kernel has grand plans for further digitalization of its business processes. One of them concerns the logistics process, which is based on the technology of simulation modeling and artificial intelligence. This will help logistics managers to ensure that the port always has the required amount of products with minimal transportation costs. The system will show the balance between road and rail transport, predict possible problems at a particular point of acceptance or shipment of products, as well as offer scenarios for solving this problem.

Another project is a CRM platform, the main purpose of which is to manage relationships with farming partners in the procurement process. This digital tool will help to have all the necessary information to determine the parameters of the

transaction. The next step in digitalization will be to supplement this platform with a sales and inventory management module. Thus, employees will have access to a single information environment and will be able to work in it. The company wants the system to be able to respond to daily changes (price changes, delivery delays, lack of trucks) and provide employees with all the necessary information while solving the problems of management and accounting.

It is worth noting that Kernel helps its partners to work more efficiently due to digital solutions. For example, reducing the costs of partner farmers and the company's costs for concluding contracts. "Farmer's Portal" is a platform based on an electronic document management system using a digital signature. The time for concluding contracts has been reduced from one week to 1-2 days, and the process has become more transparent because the farmer sees the information on the portal and through it can provide documents. Kernel also shares its experience with partner farmers in the Open AgriBusiness program.

Therefore, due to digital technologies, the business processes of the company have changed radically.

Conclusions

The digitalization of the agricultural sector is extremely important, given the many positive effects, both at the macro and micro levels. The main components of the digital cycle (areas) in which it is carried out are data collection, data analysis, data storage, data management, and data transfer and sharing. For each of them, many useful tools and methods of digitalization of agriculture have been designed, developed, and recommended for practical use.

It is currently impossible to analyze the current state of digitalization of Ukrainian and European agricultural enterprises on the basis of systematically organized statistical surveys, which requires amendments to EU Regulation № 808/2004, in particular the inclusion of agribusiness (agricultural) entities in the list of objects of state statistical surveys.

Specialists of the Food and Agriculture Organization of the United Nations have developed a methodology for assessing the needs and readiness of European and Central Asian countries to develop and implement digitalization strategies in agriculture.

In Ukraine, the state of digitalization of agriculture is extremely insufficient, it requires appropriate organizational efforts at both the macro and micro levels. There are some positive examples of the successful digital transformation of all business processes – Kernel Agricultural Holding, which clearly demonstrates the benefits of digitalization and can serve as an "ideal" for the dissemination of this innovative experience.

Abstract

Digital technologies have long been recognized as a key factor in reducing the digital divide and achieving three dimensions of sustainable development: economic growth, environmental balance, and social integration. Using information and communication technology (ICT) solutions, problems that have been a burden on the agricultural sector for too long can be solved.

According to the Food and Agriculture Organization of the United Nations, digital agriculture is the planning, development, and application of innovative ways of using information and communication technologies (ICT) in rural areas, with a focus on agriculture and food, including fisheries, forestry, and livestock. The main components of the digital cycle (areas) in which the digitalization of the agricultural sector is carried out are data collection, data analysis, data storage, data management, and data transfer and sharing. For each of them, many useful tools and methods of digitalization of agriculture have been designed, developed, and recommended for practical use.

The agricultural sector remains one of the main sectors of the Ukrainian economy. During the period 2016-2017, it amounted to 10-12% of the GDP (nominal) of Ukraine, entering one of the largest industries in the country. About 17% of the working population is employed in agriculture.

The importance of the agricultural sector is confirmed by the constant growth of foreign trade. During 2010-2017, the share of agricultural products in total exports increased from 21% to 44%, respectively. Thus, the digitalization of agriculture is relevant and extremely important for the country as a whole, as well as it is a tool for improving the efficiency of management, ensuring the current and future competitiveness of a large number of agricultural businesses.

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Посилання на статтю:
Ligonenko L.O. Digitalization of the agricultural sphere: state, problems and prospects / L. O. Ligonenko, O. L. Lanova // Економіка: реалії часу. Науковий журнал. – 2021. – № 1 (53). – С. 84-92. – Режим доступу до журн.: https://economics.opu.ua/files/archive/2021/No1/84.pdf.
DOI: 10.15276/ETR.01.2021.9. DOI: 10.5281/zenodo.4885364.

Reference a Journal Article:
Ligonenko L.O. Digitalization of the agricultural sphere: state, problems and prospects / L. O. Ligonenko, O. L. Lanova // Economics: time realities. Scientific journal. – 2021. – № 1 (53).– P. 84-92. – Retrieved from https://economics.opu.ua/files/archive/2021/No1/84.pdf.
DOI: 10.15276/ETR.01.2021.9. DOI: 10.5281/zenodo.4885364.