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Formation of information support system for the management of agricultural enterprises

Abstract
The *purpose* of the article is to generalize and present the peculiarities of the process of forming a system of information support for the management of agricultural enterprises in Ukraine. *Methodology*. General scientific (generalization, comparison, induction and deduction) and empirical and theoretical methods (analysis, synthesis) were used in the research. The use of system-structural analysis made it possible to identify the main features of the process of forming a system of information support for the management of agricultural enterprises in Ukraine. The *results* of the study showed that with the help of big data analysis in agriculture it is possible to remotely detect problems that can be used to identify nutrient deficiencies, diseases, lack or excess of water, pest and weed infestation, insect damage, etc. It is determined that the use of analytical tools based on the analysis of geographic information systems data is useful in modeling and mapping, which can be used to predict crop yields. *Practical implications*. The results of the study can be used in the management of agricultural enterprises in Ukraine. The obtained results can be directed to further research on the analysis of big data in agriculture in the management of agricultural enterprises. *Value/originality*. The scientific novelty of the results obtained is determined by the solution of an important scientific task, which is to develop theoretical provisions and practical recommendations for the formation of a system of information support for the management of agricultural enterprises in Ukraine. The work has further developed research on the use and analysis of big data in agriculture in the management of agricultural enterprises in Ukraine.

Keywords
agricultural enterprise,
information support,
management

JEL: Q13, Q14, M11

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1 Introduction

Agriculture is noted as one of the main human activities for survival. The increase in the world's population has increased the demand for food, as a result of which it is necessary to promptly address the problems of food security. In modern conditions, socio-economic development of the country is impossible without the formation of an effective agro-industrial complex. Due to the increasing competition in the world market, the process of ensuring the sustainability of the enterprise in the agricultural market is of great importance. Therefore, agriculture is noted as an ideal environment for the application of information technology. In this regard, for the effective and continuous functioning of business entities, the use of the latest information technologies in the industry will increase the productivity of agricultural production and will have a powerful positive impact on its development. In this regard, it is quite relevant and necessary in modern conditions to consider the existing trends in the formation of information support system for the management of agricultural enterprises in Ukraine.

The aim of the research is to study the process of formation of the information support system for the management of agricultural enterprises in Ukraine. To achieve the purpose of the study, the following tasks have been defined: to analyze the features of the application and analysis of big data in agriculture in the management of agricultural enterprises of Ukraine; to analyze the software used to manage agricultural enterprises of Ukraine; to identify digital technologies used in the management of agricultural enterprises. The study used general scientific and special research methods, in particular analysis and synthesis, comparison, generalization, system-structural analysis.

2 Big data in agriculture

Building on past achievements, the current wave of technological advances focuses on the creation, use, consolidation, analysis and exchange of agricultural and other data in digital format in order to increase the resilience and productivity of agricultural systems. According to the Food and Agriculture Organization of the United Nations, digital agriculture is the planning, development and application of innovative ways to use information and communication technologies (ICTs) in rural areas, with a focus on agriculture and food, including fisheries, forestry and livestock (Liu et al., 2020; Ang, Seng, 2021).

The implementation of precision agriculture technology generates a huge amount of diverse data from the agricultural sector, where data collection includes soil characteristics, seeding rates, crop yields, which can be combined with historical records such as weather conditions, topography and crop productivity. Big data is noted as a powerful platform for storing a variety of collected data and consists in analyzing the resulting data to make effective decisions. The term "big data in agriculture" helps to understand the need to invest in infrastructures for storing and processing agricultural data. Big data promises accurate data storage, processing and analysis that was previously impossible with traditional methods. It allows searching, aggregating, linking different sets of agricultural data in order to obtain optimal conclusions on agricultural management. Linking factors such as remotely sensed data (crop condition, area index, soil mapping, etc.) with statistical data (rainfall, temperature, and previous yields) supports decision making such as recommendations for increasing yields, yield forecasting, fertilizer recommendations, pest control, etc. (Nandyala, 2016).

Big data in agriculture is a huge amount of digital data that is difficult to manage and analyze using traditional software and technologies (Kshetri, 2014). Big data in agriculture is often used to describe a modern trend in which the combination of technology and advanced analytics creates a new way of useful information processing. For example, Gartner, Inc. defines big data with a similar interpretation: "Big data is viewed as voluminous, high-velocity and diverse information assets that require cost-effective, innovative forms of information processing to improve insight and decision-making." (Gartner, 2013)

The collected big data in agriculture can be classified as machine generated data, process generated data and human generated data (Abawajy, 2015). Machine-generated data includes data from sensors, drones, GPS, etc. Process-generated data include data collected from farms, such as information on sowing, monitoring and recording of agricultural processes such as fertilization, as crop yields are closely related to geographical location, which is referred to as spatial data, and stored as coordinates to locate an area (Yan-e, 2011).

Big data in agricultural analysis can be applied in agriculture with the support of experienced agricultural experts (farmers, agricultural researchers, agricultural market analysts, distribution specialists, etc.) (Nandyala, 2016). Farmers and related organizations can benefit economically from very large volumes of diverse data through high-speed analysis of agricultural information (Waga, Rabah, 2014; Lokers et al., 2016). Big data in agriculture can generally be divided into five stages: data collection, data storage, data transformation, data analysis, data marketing (see Figure 1).

A variety of big data analytics software tools are available in agriculture (see Table 1) (Kamilaris et al., 2017; Bhat, Huang, 2021).

Various agricultural issues related to crop selection, irrigation methods, fertilizer selection and yield forecasting can be solved with the help of big data technologies. The collected data is unstructured and heterogeneous, and NoSQL technology has become popular for storing such data. For storing heterogeneous data and performing preprocessing, a NoSQL data model such as Mongo DB, Couch DB, and HBase is best suited.

Recently, machine learning has been used by data analysts to exploit the information hidden in big data by identifying associations and understanding patterns and trends in the collected data (Garg, Himanshu, 2016). In agriculture, the huge amounts of data that are regularly collected require analysis and interpretation using machine learning methods (Weersink et al., 2018). Research scientists are trying to develop a large-scale data analysis tool using machine learning. The collected data has many problems for direct application of machine learning, so data transformations are needed to solve problems such as data redundancy, data noisiness, data inconsistency, and data imbalance.

As a result of big data analysis in agriculture, mobile messages can be sent that are related to crop selection and best farming practices, which can be provided to farmers to adapt to analytical suggestions. The results obtained from the analysis can be best understood through data visualization, namely, with the help of

Data collection is defined as the process of obtaining a huge amount of heterogeneous data from different sources, such as weather stations, remote mapping, cropping patterns, field characteristics, etc., which are available on the website of the Ministry of Agrarian Policy and Food of Ukraine.

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Data storage is a key challenge for applications that work with large amounts of data, and NoSQL technologies are currently gaining popularity in this process.

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Data transformation is a step in which multiple data representing the same parameter must be integrated into one consistent representation.

↓

Data analysis extracts meaning from data and interprets the results, turning them into information.

↓

Marketing data integrates analytics results to make decisions on further processes.

FIGURE 1 Big data in agriculture
Source: compiled by the authors according to official data (Javaregowda, Indiramma, 2019)

visualization tools such as R, Rapid miner, D3, it is easy to determine the structure of sown areas, weather conditions, price fluctuations, etc. (Javaregowda, Indiramma, 2019).

3 Features of the use of digital technologies in agriculture

The report "Digital Opportunities for Improving Agricultural Policy" (OECD, 2019) identifies the stages of digital technology application in agriculture and its most important components: data collection, data analysis, data storage, data management, data transmission and exchange.

Stage 1 – data collection. The collection of basic data in digital agriculture should be done 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. Recently, significant progress has been made in using satellite remote sensing to obtain more accurate data in agriculture.

Problems in crops can be detected remotely even before they can be detected visually. Remote sensing images can be used to detect nutrient deficiencies, diseases, lack or excess of water, pest

TABLE 1 Software tools for big data analysis

Category	Software
Image processing tools	IM Toolkit, VTK Toolkit, OpenCV Library
Cloud platforms	Cloudera, EMC Corporation, IBM InfoSphere BigInsights, IBM PureData System, Aster SQL MapReduce, Pivotal Gemfile, Pivotal Greenplum, Map R Converged Data Platform, Hortonworks and Apache Pig
GIS systems	ArcGis, Autodesk, Map Info, MiraMon
Machine learning tools	Google TensorFlow, R, Weka, Flavia, Scikit-learn, SHONGUN, miPy, Mipack, Apache Mahout, Milib and Ortx
Large databases	Hive, HadoopDB, MongoDB, ElasticSearch, Apache HAWQ, Google Big Table, Apache HBASE, Cassandra, Rasdaman, MonetDB/ SciQL, PostGIS, Oracle GeoRaster, SciDB
Message-oriented middleware	MOTT, RabbitMQ
Modeling and simulation	AgClimate, GLEAMS, LINTUL, MODAM, OpenATK
Statistical tools	Norsys Netica, R, Weka
Time series analysis	Stata, RATS, MatLAB, BFAST

Source: compiled by the authors according to official data (Kamilaris et al., 2017; Bhat, Huang, 2021) and weed infestations, insect, hail or wind damage. This information is valuable because it is used as the basis for variable rate fertilizer and pesticide applications.

Information from remote sensing images allows farmers to treat only affected areas of the field. Crowdsourcing of information promotes public engagement and participation in science and innovation. Currently, there are publicly available programs that aim to involve citizens' efforts in data collection or processing. These applications should include elements of gamification (i.e., adding game elements to existing applications) 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 could be much wider.

Stage 2 – data analysis. The use of analytical tools based on GIS data analysis is useful in modeling (watersheds, relief) and mapping (vegetation cover), which in turn can be used to predict crop yields. Digital technologies can harness the accumulated knowledge of groups of people and expand access to information, finance and markets through crowdsourcing. First of all, this digital tool helps with information gathering, but it can also be used for analysis (USAID, 2013).

Plantwise is an initiative that offers farmers tools to diagnose crops and pests. Plantwise collects information from farmers about soil conditions and other risk factors and then transmits data from their fields to a central Plantwise database. This database is then analyzed by its staff. In exchange for their participation, farmers receive technical assistance via SMS and voice messages on how to get rid of or avoid pests, thereby reducing crop losses. Figure 2 shows four main categories of AI applications in agriculture (Tanha et al., 2020).

Stage 3 – data storage. As the amount of information is constantly increasing, an agricultural enterprise needs a reliable and easily accessible way to store data. Cloud services allow you to increase flexibility, reduce infrastructure requirements, optimize processes, increase availability and efficiently process large amounts of data. Cloud-based software (SaaS) is expected to lead the farm management software market in the future. When using the software, users only need to access the records provided by the providers through appropriate web browsers (Alan, 2021).

Stage 4 – data management, which is provided by distributed ledger technology, namely blockchain. According to the FAO study, blockchain is widely used in areas such as agricultural insurance, land registration, supply chains, etc. For example, by increasing the transparency of agricultural supply chains, blockchain can help ensure traceability of products from the point of origin to the retail store. It can increase consumer confidence in the products they buy and reward producers who use good agricultural practices to grow their products. Ultimately, it can lead to responsible consumption, food safety, as well as reduce food fraud and improve brand reputation (FAO, 2019).

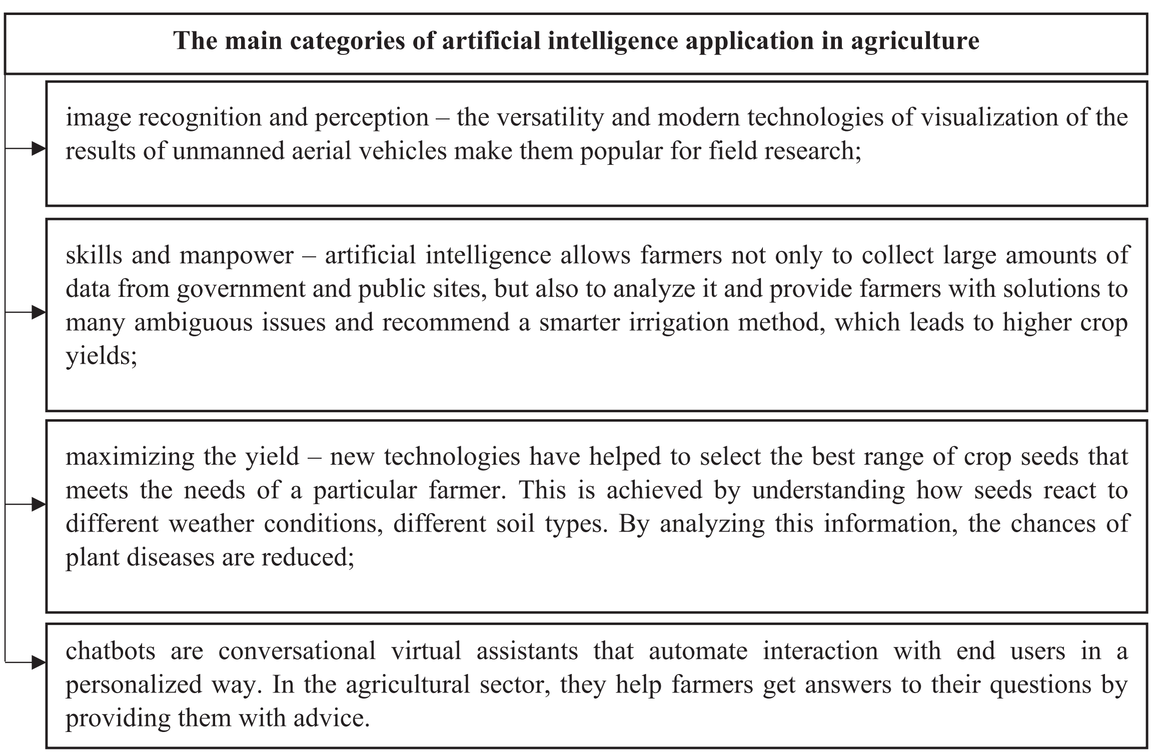

FIGURE 2 Main categories of artificial intelligence application in agriculture
Source: compiled by the authors according to official data (Tanha et al., 2020)

Stage 5 – data management, transfer and exchange. This area of digitization includes technologies that actually use the transfer or exchange of data to facilitate other types of transactions, such as property, communication (between people or digital devices) and digital services. Farmer age and irrigation use have been shown to be factors influencing the tendency to share farm data. Older farmers are less likely to share their data than younger farmers, most likely because the older generation is more skeptical and less familiar with new technologies. In addition, producers who do not use irrigation systems are less likely to share their data, which may be related to lower production intensity. Farmers with more technical skills, namely those who use a mobile phone with internet access and more digital technologies in agriculture, were less inclined to share their data, possibly because they have a better understanding of agricultural problems, which allows them to solve them at their own discretion (Michael et al., 2016). Thus, the directions and opportunities for digitalization in agriculture are extremely diverse and multifaceted.

4 The state of digitalization of Ukrainian and European agricultural enterprises

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 by type of economic activity, but according to the methodology of this state statistical observation, which is developed in accordance with EU Regulation No. 808/2004, agriculture is not the object of research. Therefore, it is currently impossible to analyze the state of digitalization of the agricultural sector of Ukraine based on statistical observations (State Statistics Service, 2022).

Thus, the situation in Ukraine is similar to that in the EU. The official Eurostat website displays quite a wide range of information, broader and more interesting, including general information on ICT systems, Internet access (including mobile Internet use), e-commerce and e-business use (cloud computing, software, Internet of Things, big data analysis, 3D printing, robotics, artificial intelligence, etc.). However, the established statistical observation also ignores agriculture for unclear reasons.

Given the role and importance of agriculture for most EU countries and their food security, a gap in the methodology of statistical observations was identified. EU Regulation No. 808/2004 needs an urgent correction by expanding the list of spheres (types of activity) for which relevant information is collected, in particular the inclusion of companies operating in the agricultural sector (Eurostat, 2022). Despite the lack of systematized information (based on systematically organized statistical observations), certain conclusions about the state of digitization of both Ukrainian and European farmers can be drawn on the basis of information from special studies conducted in this area.

It was found that about 10% of Ukrainian agricultural companies use digitalization, which is extremely insufficient (National Investment Council, 2018). An example of effective implementation of digitalization of business processes in management can be such agricultural enterprises as Kernel, AgriChain, Syngenta and Ukrlandfarming. It is established that Kernel uses digital technologies in all areas defined in Figure 1 by the 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 became necessary for further quality solutions.

5 Conclusions

Based on the study, it can be concluded that in the conditions of intensive implementation of diversification of agricultural enterprises in the system of ensuring their competitiveness through the use and analysis of big data in agriculture, the issue of forming a system of information support for the management of agricultural enterprises in Ukraine is becoming increasingly relevant among scientists. It has been established that big data in agriculture can be useful through yield recommendations, yield forecasting, fertilizer recommendations, pest control, market forecasting, marketing and sales optimization, productivity improvement, asset condition monitoring, etc.

It is found out that it is impossible to analyze the current state of digitalization of agricultural enterprises in Ukraine on the basis of systematically organized statistical research, since it is necessary to amend EU Regulation No. 808/2004 on the inclusion of agribusiness (agriculture) in the list of objects of state statistical observations. It is determined that the current state of digitalization of agriculture in Ukraine is extremely insufficient and requires appropriate organizational efforts at both macro- and micro-levels. At the same time, some Ukrainian agricultural enterprises successfully apply the benefits of digitalization in their business processes.

The results of the study can be used to apply modern approaches to the management of agricultural enterprises in the context of digitalization of business processes, which will stimulate agricultural activity, increase profits and ensure the competitiveness of the agro-industrial complex.

References

[1] Liu, X., Zhai, H., Shen, Y., Lou, B., Jiang, C., Li, T., Hussain, S. B., & Shen, G. (2020). Large-scale crop mapping from multisource remote sensing images in Google Earth engine, *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.,* vol. 13, no. 13, pp. 414–427.

[2] Ang, K. L.-M., & Sen, J. K. P. (2021). Big Data and Machine Learning With Hyperspectral Information in Agriculture, *IEEE Access*, vol. 9, pp. 36699–36718. DOI: https://doi.org/10.1109/ACCESS.2021.3051196

[3] Kamilaris, A., Kartakoullis, A., & Prenafeta-Boldú, F. X. (2017). A review on the practice of big data analysis in agriculture, *Comput. Electron. Agricult.,* vol. 143, no. 1, pp. 23–37.

[4] Bhat, S., & Huang, N.-F. (2021). Big Data and AI Revolution in Precision Agriculture: Survey and Challenges. *IEEE Access,* 9, 110209–110222. DOI: https://doi.org/10.1109/ACCESS.2021.3102227

[5] Nandyala, C. S. (2016). Big and Meta Data Management for U-Agriculture Mobile Services, *International Journal of Software Engineering and Its Applications*, vol. 10, no. 2.

[6] Kshetri, N. (2014). The emerging role of Big Data in key developmental issues; opputunities, challenges and concerns, Big Data and Society.

[7] Gartner (2013). E-source: http://www.gartner.com/it-glossary/big-data

[8] Abawajy, J. (2015). Comprehensive analysis of big data variety landscape. *International journal of parallel, emergent and distributed systems,* 30(1), 5–14.

[9] Yan-e, D. (2011). Design of Intelligent Agriculture Management Information System Based on IoT, *2011 Fourth International Conference on Intelligent Computation Technology and Automation,* Shenzhen, Guangdong, 2011, pp. 1045–1049.

[10] Waga, D., & Rabah, K. (2014). Environmental conditions' big data management and cloud computing analytics for sustainable agriculture. *World Journal of Computer Application and Technology,* vol. 2(3), pp. 73–81.

[11] Lokers, R., Knapen, R., Janssen, S., van Randen, Y., & Jansen, J. (2016). Analysis of Big Data technologies for use in agro-environmental science. *Environmental Modelling & Software,* vol. 84, pp. 494–504.

[12] Garg, R., & Himanshu, A. (2016). Big Data Analytics Recommendation Solutions for Crop Disease using Hive and Hadoop Platform. *Indian Journal of Science and Technology,* vol. 9, p. 32.

[13] Weersink, A., Fraser, E., Pannell, D., Duncan, E., & Rotz, S. (2018). Opportunities and challenges for Big Data in agricultural and environmental analysis. *Annual Review of Resource Economics,* vol. 10, pp. 19–37.

[14] Javaregowda, M., & Indiramma, M. (2019). Role of Big Data in Agriculture. *International Journal of Innovative Technology and Exploring Engineering,* vol. 9, pp. 3811–3821.

[15] The Organization for Economic Co-operation and Development (OECD) (2019). Digital Opportunities for Better Agricultural Policies. 234 p. E-source: https://www.oecd-ilibrary.org/agriculture-and-food/digital-opportunities-for-better-agriculturalpolicies_571a0812-en

[16] United States Agency for International Development (USAID) (2013). Crowdsourcing Applications For Agricultural Development In Africa Introduction. USAID. 6 p. E-source: https://www.agrilinks.org/sites/default/files/resource/files/Crowdsourcing_Application s_for_Agricultural_Development_in_Africa.pdf

[17] Tanha, T., Dhara, S., Nivedita, P., Hiteshri, Y., & Manan, S. (2020). Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides. *Artificial Intelligence in Agriculture,* vol. 4, pp. 58–73. E-source: https://www.sciencedirect.com/science/article/pii/S258972172030012X

[18] Alan, S. (2021). Data Storage Methods for Businesses. *Vxchnge.* E-source: https://www.vxchnge.com/blog/business-data-storage-methods

[19] Food and Agriculture Organization (FAO) and International Telecommunication Union (ITU) (2019). EAgriculture in Action: Blockchain for Agriculture. 72 p. E-source: http://www.fao.org/3/CA2906EN/ca2906en.pdf

[20] Michael, H. C., Bradley, D. L., & Joe, D. L. (2016). Factors Influencing Producer Propensity for Data Sharing & Opinions Regarding Precision Agriculture and Big Farm Data. University of Nebraska, Lincoln, vol. 3, 26 p. E-source: https://digitalcommons.unl.edu/ageconworkpap/48/

[21] State Statistics Service of Ukraine (2022). E-source: http://www.ukrstat.gov.ua/

[22] Eurostat (2022). E-source: https://ec.europa.eu/eurostat

[23] National Investment Council of Ukraine (2018). Agricultural sector of Ukraine: Securing the global food supply.

[24] Ligonenko, L. O., & Lanova, O. L. (2021). Digitalization of the agricultural sphere: state, problems and prospects. *Economics: time realities. Scientific journal,* vol. 1 (53), pp. 84–92. DOI: https://doi.org/10.15276/ETR.01.2021.9

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