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THE IMPACT OF DIGITALIZATION ON THE DEVELOPMENT OF THE AGRO-FOOD SPHERE

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Abstract: *The agro-food sphere is one of the key industries in the country's economy and plays a major role in ensuring food security. The development of the agro-food sphere requires the development and implementation of innovative projects in this field. The creation and implementation of such innovative projects require the availability of information support, which includes complete and up-to-date information about the objects and processes related to the project. It has been proven that the innovative development of the agro-food sphere is closely related to the digitalization process in this field. It is noted that digitalization in the management of agriculture and the agro-food sphere opens up new opportunities for increasing the efficiency, transparency, and sustainability of this industry. The main directions of implementing digitalization in the agro-food sphere have been studied, including the creation of electronic registers and databases, and the development of decision support systems. The integration of e-government services in the agro-food sphere offers significant opportunities for improving the efficiency of public administration, enhancing service delivery, improving interaction between public authorities and agricultural market entities, and ensuring sustainable agricultural development. The author has developed a methodology for the integral assessment of the level of e-government development in the country. The integral assessment is based on initial indicators, including those defined by the United Nations Department of Economic and Social Affairs. The method of the modified principal component was used to determine the weighting coefficients of these indicators in the integral assessment. Integral assessments of the components of the agro-food sphere have been determined: the food industry, retail trade in food products, and indicators related to the protection and preservation of the environment associated with the agro-food sphere. A significant correlation has been found between these integral assessments and the integral assessment of digitalization.*
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Keywords: digitalization, agro-food sphere, integral assessment, e-government

1. Introduction

An important component of the country's national security is food security, which involves the state ensuring the population's needs for essential quality food products for their livelihood. The agro-food sphere, a key sector of the economy, plays a major role in ensuring the country's food security. The development of the agro-food sphere, which enables the achievement of the necessary level of food security, requires the development and implementation of innovative projects in this field. These projects involve the use of modern equipment, the introduction of the latest technologies in production, the production of environmentally friendly products, the use of renewable energy sources, environmental protection, the organization of production management using information and communication technologies, the use of internet technologies in marketing activities, and the development of measures aimed at improving the social living standards of the population. The creation and implementation of such innovative projects require the availability of information support, which includes complete and up-to-date information regarding the objects and processes related to the project. Since the volume of this information is very large and accumulates rapidly, a set of tools and methods of Big Data must be applied for processing and utilizing the data. Thus, the innovative development of the agro-food sphere is closely linked to the process of digitalization in this sector.

The concept of digitalization is the subject of many scientific studies and is interpreted differently by various authors. The consulting company Gartner considers digitalization to be the improvement of business organization based on the modification of business models using digital technologies (Digitalization, 2024). According to the definition proposed by the OECD (OECD, 2019), digitalization is the process of using interconnected data and digital technologies to create new and modify existing types of activities.

Digitalization encompasses almost all forms of political, economic, and social life, with digital technologies having advantages over analog ones. Among the main areas of digitalization implementation in Ukraine are the digital economy, agriculture, environmental protection and natural resources, social development of local communities and territories, public safety, and e-government.

The basis of the digital economy and the main factor of its growth is the digitalization of business and industry. The implementation of digital technologies in Ukrainian industry increases its efficiency, and in some cases, such technologies become the foundation of production and product strategies. The driving force of digital technologies fundamentally changes existing business models and production stages, leading to the emergence of fundamentally new innovative products. The digital transformation of industry occurs thanks to cloud technologies, new industrial applications, Big Data, robotics, smart applications, 3D printing, cyber systems, and more.

To encourage businesses to use digital technologies, it is necessary to make these technologies accessible in Ukraine so that there is a desire to connect to the digital infrastructure. This will significantly accelerate the development of their own business, increase the level of modernization, and optimize operations.

2. Literature overview

The problems of innovative development in the agri-food sector in Ukraine are the subject of research by many scientists. In the work of (Goncharenko et al. 2023), it is noted that as a result of Russia's full-scale war against Ukraine, global food security is under threat, causing damages of $2.1 billion due to the destruction of agricultural lands. Using correlation-regression analysis, multivariate statistical analysis, and the taxonomy method, the authors show that the greatest negative impact on the innovative development of Ukrainian agriculture is the reduction in spending on research and development in this field. The results of the study emphasize the necessity of supporting scientific investments to ensure the resilience of the agricultural sector.

The current issues in the development of Ukraine's agricultural sector include ensuring global food security in the context of military actions, increasing the production efficiency of agriculture, and overcoming the contradictions between private interests and public interests. Scientists consider production optimization in this sector an important means to solve these problems, which will significantly reduce production costs, increase profit, account for risks, and achieve balanced development (Ilchuk et al., 2023).

An important factor in the development of agribusiness, improving agricultural production, and increasing the efficiency of resource use is digital transformation. The role of

digital transformation in the sustainable development of the country's economy is studied in the work of (Musiiets, Riabets, 2023). The authors believe that the digital transformation of the global economic system is a key imperative for ensuring sustainable development on an innovative basis. They emphasize the undeniable role of digital innovations in enhancing the competitiveness of entrepreneurial structures and national economies. The authors also identify significant risks of the uncontrolled spread of digitalization and propose mechanisms for their mitigation, which are already being implemented by democratic governments or have clearly defined timelines for future implementation. The scientific results obtained by the authors can be effectively applied to solve the development challenges of the agro-food sphere.

The implementation of digital technologies, such as big data and artificial intelligence, allows for the analysis and prediction of production processes, which improves product quality and creates a transparent supply chain. Scientists are studying the impact of digital transformation on agricultural relations and their connection with general economic processes in Ukraine. Innovations aimed at increasing the efficiency and competitiveness of the agricultural sector under digital transformation are considered in the work of Buiak (2023).

Several authors explore specific aspects of digitalization in the agro-food sphere. In the article by Rotz et al. (2019), the authors focus on aspects such as the implementation of digital technologies in the agro-food system and the neglect of political factors in the decision-making space. They address key issues in managing agricultural technologies and data systems, including data ownership, production, and security, and assess how the political and economic landscape can be changed to support greater equity in agriculture. The authors propose providing marginalized farmers with open-source platforms and scalable technologies, which will create shorter and more democratic supply chains.

A program for creating a digital platform for cooperation and balancing agricultural production, aimed at a wide range of users including agricultural producers, rural residents, consumers of agricultural products, environmental organizations, and government authorities, is proposed in the work of Iarmolenko (2019). It is noted that the digitalization of the agricultural sector occurs in real, virtual, and institutional environments, each of which has its specific tasks and functions. The authors have proven that priority projects for the sustainable development of agricultural production should include improving the regulatory environment, developing ICT

infrastructure, ensuring accessible digital education, and forming an agro-digital platform as the core of a national digital business ecosystem. The agro-digital platform helps reduce transaction costs and contributes to achieving national goals while considering regional peculiarities.

An important component of the agro-food sphere is the organization of environmental protection and preservation. The legal regulation of digitalization in environmental protection is the subject of research in the work of Ilkiv (2024). The author analyzes the legal support for the digitalization of public participation in making environmentally significant decisions in Ukraine, emphasizing the significant potential of digital technologies for ensuring environmental safety and sustainable development. The author also underscores the importance of improving procedures for public involvement in environmental processes, noting that digitalization contributes to the creation of an inclusive society, improving environmental quality, and expanding ways for citizens to collaborate with the authorities and businesses.

Korczelli-Oleinychak Y.K. and Kazmir L.P. (2021) investigate the role of digital technologies in industrial development. The scientists argue that the progress of digital technologies promotes economic growth and the activation of industrial production. They propose a matrix structure for forming program tasks to support the digitalization of the region's industrial system, which will coordinate the activities of government authorities, local self-government, scientific and educational institutions, businesses, and public organizations to support measures aimed at digitalizing the region's industrial system, generating, and absorbing relevant innovations. Since the food industry is an important component of the agro-food sphere, the results obtained by the authors can be used in the implementation of digital technologies in this field.

The object of study in the article (Sgroi, 2022) is digital food centres. The author defines the Food Hub and describes the models used in its structures.

The influence of business networks within research projects on digital innovations of small and medium-sized agri-food enterprises is investigated in (Silvestri, et al., 2023). The authors note that digital innovations contribute to the competitiveness and sustainability of these agri-food enterprises.

The article (Glaros, et al., 2023) examines how and by whom the transformation of the digital agri-food system is carried out. Three transformation frameworks are identified: digital

tools for optimising enterprise productivity; overcoming inequality in access to digital tools; and technologies for creating traceable agri-food systems. The authors recommend that public and private actors cooperate with scientists and involve farmers in the development of new transformational approaches.

The new opportunities provided by digitalisation for trade in the agricultural and food sectors are discussed in (Jouanjean, 2019). The author notes the importance of digital transformation for all participants in the value chain, including support services, logistics, and governments.

In the article (Nwafor, et al., 2022), the authors note that information and communication technologies play an important role in the transition to a sustainable food chain, which includes the production, processing, distribution and consumption of food. The key challenges to the effective use of these technologies are lack of access to ICT tools, low computer literacy, and lack of funds.

The authors of the article (Rotz, et al., 2019) believe that management decisions made in the agri-food system are predominantly technocentric, and the impact of digital technologies on supporting agro-ecological systems is not given enough attention. It is noted that decision-makers in this area need a timely assessment of agri-food digitalisation that takes into account political and economic factors.

The institutional structure for Industry 4.0, designed to guide and support the development of techno-entrepreneurs in the field of digital agriculture, is proposed in (Smidt & Jokonya, 2023).

The state of agriculture and its potential in the context of digitalisation is assessed through systemic and situational analysis (Rodino, et al., 2023). The introduction of digital technologies is leading to a significant transformation of management and production processes in agriculture, with scientific and technological progress playing a crucial role. Digital transformation affects material and human resources, and contributes to increased crop yields and livestock productivity. Investments in digital infrastructure development help to improve the living conditions of the rural population, develop farms, and promote agriculture

The main obstacles to the introduction of digital technologies in the agricultural sector are low skills, insufficient investment, uncertainty of economic benefits, and insufficient data

protection (Bachev, 2020). The main tasks of the state administration are to implement measures to improve the skills of employees, encourage young professionals, introduce internationally recognised standards, improve the legal framework for data protection, and provide access to high-speed Internet.

3. Article Purpose

Development of a methodology for integral assessment of the level of digitalization in Ukraine and assessment of its impact on comprehensive assessments of the development level of components in the agro-food sphere.

The work employs methods of integrated assessment, modified principal component analysis, and correlation analysis.

4. Methodology and Results

Digitalisation in the management of agriculture and the agri-food sphere opens up new opportunities for increasing the efficiency, transparency and sustainability of this industry. The main areas of digitalisation in the agri-food sphere include the creation of electronic registers and databases, development of decision support systems, use of precision farming, automation and robotisation of production processes, and automation of financial support to farmers.

The introduction of electronic land registers, crop and livestock registers provides up-to-date information on available resources and their use, which makes it possible to plan activities based on accurate data. To support decision-making in the areas of resource allocation and plant protection, it is advisable to develop and implement information systems that analyse large amounts of data. The use of data obtained through satellite imagery, drones and other sources to monitor crop conditions, determine the need for fertilisers and plant protection ensures more efficient and cost-effective farming. The introduction of robotic systems for field cultivation, harvesting and animal care reduces the need for manual labour and increases productivity. The effective use of robotics in agriculture is inextricably linked to the processes of obtaining, processing, storing, transmitting and using large amounts of data. The accuracy, relevance, and reliability of this data determines the efficient operation of artificial intelligence and, as a result, the correctness of decisions made in automatic mode. Thus, the form of information presentation

largely determines the effectiveness of robotics. The technologies used in agricultural production provide data that needs to be digitised and analysed, and significant correlations between indicators need to be identified. Thus, the introduction of robots in agricultural production is closely linked to the digitalisation process.

Food processing companies that process agricultural raw materials and produce food products from them play a significant role in the agricultural sector. To improve the efficiency of these enterprises, it is necessary to implement operational production management systems. Automated Manufacturing Execution Systems (MES) are an effective means of production management that enables the rapid implementation of large-scale projects. These systems provide users with up-to-date, complete and reliable information on the status of production processes and thus facilitate optimal management decisions.

ERP systems are an effective tool for managing enterprises, including those in the agri-food sphere. They provide comprehensive management of production, human, financial and other resources, carry out monitoring and analytical research, and keep records of interaction with partners and customers. ERP ensures the integration of various business processes into a single system, which makes it possible to optimise them, avoids re-entering the same data, and creates a user-friendly interface. Such integration is of particular importance in the agri-food sector, which combines the processes of production, transportation and sales of products. ERP systems include artificial intelligence technologies, machine learning, the Internet of Things, and other modern technologies to improve the efficiency of economic system management (Lapchuk, 2021).

The Ministry of Digital Transformation of Ukraine is the central executive body that forms and implements the state policy of digitalisation and informatisation of society. This ministry is responsible for integrating digital technologies into all spheres of public life, thereby contributing to the development of the digital economy and digital democracy. One of the main tasks of the Ministry of Digital Transformation is to manage the development of the infrastructure of electronic registers, which are the basis for many types of administrative and commercial services.

The State Agrarian Register is a key tool for the effective management of Ukraine's agricultural sector. The registry stores information on land plots, ownership and use rights, as

well as on agricultural enterprises and their status. Open access to the registry's information helps farmers, investors and regulators to obtain the necessary data to make informed decisions. The agrarian registry allows the government to effectively monitor the agricultural sector, plan agricultural policy and control the implementation of legislation.

Automation of financial transactions for managing subsidies, loans and insurance through automated systems based on the state agricultural registry ensures timely provision of financial support to farmers, objectivity and transparency in the process of subsidies allocation, contributes to more efficient use of public resources and is a key factor in strengthening farmers' trust in state institutions.

There is a need to work on further integration of the registry with other public and private information systems to ensure a unified digital ecosystem. It is also important to provide ongoing education and training for users of the system to increase their digital literacy.

E-governance is a central element of the transformation that ensures the integration of modern IT solutions into public administration and service processes. E-governance involves the use of information and communication technologies that facilitate the effective operation of the government and facilitate access to public services.

The introduction of e-governance in the agri-food sphere ensures an increase in production productivity through the efficient use of resources and optimisation of production processes, improvement of product quality based on the controlled use of agro-technologies, reduction of production costs, optimisation of logistics, environmental sustainability and rational use of natural resources.

The integration of e-government services in the agri-food sphere opens up significant opportunities to increase the efficiency of public administration, improve service delivery, improve interaction between government agencies and agricultural market players, and ensure sustainable agricultural development. E-governance plays a key role in simplifying economic processes, reducing corruption and increasing the transparency of public administration.

An important component of e-governance is the development of Internet penetration. The percentage of the Ukrainian population with access to the Internet increased from 34% in 2011 to 71.8% in early 2022. However, Internet access rates in rural areas remain low, indicating the need for further development of digital infrastructure.

Priority areas for the implementation of e-governance include data integration and standardisation, cybersecurity, development of e-services, e-democracy, development of digital literacy, electronic identification and trust services.

4.1. Integral assessment of digitalisation development in Ukraine

We will assess the impact of digitalisation in governance on the development of the agri-food sphere. Since one of the most important components of digitalisation in governance is e-governance, we will define a comprehensive integrated assessment of e-governance development in Ukraine.

For an integrated assessment of the level of e-governance development in Ukraine, we will use the indicators defined by the Department of Economic and Social Affairs of the United Nations Secretariat, a list of which is given in Table 1.

Table 1 Indicators for assessing the level of e-government development in Ukraine

Designation	Index	Description
x_1	Online Service Index (OSI)	An indicator that reflects the provision of online e-government services and is calculated on the basis of the indices of institutional framework (IF), service provision (SP), content provision (CP), technology (TEC) and e-participation (EPI)
x_2	Human Capital Index (HCI)	The indicator is composed of four components: adult literacy rate; gross primary, secondary and tertiary enrolment rates; years of schooling expected; and average years of schooling
x_3	E-Participation Index (EPI)	The index measures online participation using a three-point scale that distinguishes between information provision, consultation and decision-making
x_4	Percentage of Individuals using the Internet	Percentage of people who used the Internet from any location in the last three months
x_5	Mobile cellular telephone subscriptions per 100 inhabitants	Mobile/cellular telephone refers to a portable telephone subscribed to a public mobile telephone service using cellular technology

x_6	Fixed (wired)-broadband subscriptions per 100 inhabitants	Fixed subscriptions to high-speed public Internet access or TCP/IP connections with a downstream speed equal to or greater than 256 kbps.
x_7	Wireless broadband subscriptions per 100 inhabitants	The number of mobile broadband data and voice subscriptions and mobile broadband data-only subscriptions to the public Internet.

Indicators x_1 and x_2, together with the Telecommunications Infrastructure Index (TII), are used to determine the composite index – the e-Government Development Index (EGDI). When calculating the EGDI index as a weighted average of these components, the weighting coefficients of these indicators are assumed to be equal. However, in an integrated assessment of the level of digitalisation in Ukraine, it is necessary to take into account the existence of correlations between these indicators, which makes it advisable to use the modified principal component method to determine their weighting coefficients. Indicators x_4, x_5, x_6 and x_7 are components of the Telecommunications Infrastructure Index (TII), but in determining this index, the weighting of the indicators is assumed to be equal, i.e., the existence of correlations between them is not taken into account. Therefore, in this case, when using these indicators to determine an integrated assessment of the level of digitalisation in Ukraine, it is advisable to use the modified principal component method.

The peculiarity of the integrated assessment of the level of digitalisation development in Ukraine is that the primary indicators are indices calculated using certain methods. The author used a similar approach when assessing the level of corruption in the country (Panasenko et al., 2021).

The research is based on the values of these indicators for the retrospective period from 2014 to 2022 (United Nations E-Government Survey, 2014-2022). The value of the indicator x_i in the t-th year of this period is denoted by xi (t).

To determine the integrated assessment of the level of digitalisation development in Ukraine, the indicators x_i should be normalised, that is, brought to a comparable form. The normalised indicators y_i should be dimensionless, linearly dependent on x_i and vary in the range [0;1], with the value 1 corresponding to the best value of the indicator x_i. This will make it possible to create a linear combination of the resulting normalised indicators, which we take as

the desired integral score. Since all indicators x_i are stimulants, that is, their growth corresponds to an increase in the level of digitalisation, we use the equality:

$$y_i(t) = \frac{x_i(t) - x_i^{min}}{x_i^{max} - x_i^{min}} \quad (1)$$

where x_i^{min} – the minimum value of the indicator x_i during the retrospective period, and x_i^{max} – is its maximum possible value.

The integral estimate *W(t)* of the level of digitalisation development in Ukraine is determined by the equation:

$$W(t) = \sum_{i=1}^{7} \alpha_i \, y_i(t) = \sum_{i=1}^{7} \alpha_i \frac{x_i(t) - x_i^{min}}{x_i^{max} - x_i^{min}} \quad (2)$$

where α_i – weighting coefficient of the indicator x_i.

To determine the weighting coefficients α_i, we use the principal component method, which makes it possible to significantly reduce the dimensionality of the data set while ensuring minimal loss of useful information (Eremenko, Osintseva, 2022).

According to this method, to determine the weighting coefficients a_i we calculate the covariance coefficients between the indicators $y_i = \frac{x_i(t) - x_i^{min}}{x_i^{max} - x_i^{min}}$ according to the formula:

$$cov(y_{i_1}, y_{i_2}) = \sum_{t=1}^{T} (y_{i_1}(t) - \overline{y_{i_1}})(y_{i_2}(t) - \overline{y_{i_2}}) \quad (3)$$

Where $\overline{y_{i_1}}$ and $\overline{y_{i_2}}$ – are the average values of y_{i_1} and y_{i_2} during the lookback period.

Determine the maximum eigenvalue λ of the matrix K, whose elements are these coefficients. This value is equal to the maximum root of the equation $\det(K - \lambda E) = 0$, where E – unit matrix of dimension 7×7, a $\det(K - \lambda E)$ – determinant of a matrix $K - \lambda E$. The value of λ corresponds to the eigenvector $L = \{l_1, l_2, \dots, l_7\}$, whose components l_i are solutions to the system of equations $KL = \lambda L$. The weighting coefficients α_i are determined from the equation:

$$\alpha_i = \frac{l_i^2}{\sum_{i=1}^{7} l_i^2} \quad (4)$$

The covariance matrix for the set $\{x_i\}_{i=1}^{7}$ of e-government indicators in Ukraine is as follows:

$$K=\begin{pmatrix} 0{,}061 & 0{,}002 & 0{,}035 & 0{,}043 & -0{,}013 & 0{,}008 & 0{,}064 \\ 0{,}002 & 0{,}005 & -0{,}007 & 0{,}010 & 0{,}002 & 0{,}001 & 0{,}014 \\ 0{,}035 & -0{,}007 & 0{,}053 & 0{,}012 & -0{,}016 & 0{,}001 & 0{,}011 \\ 0{,}043 & 0{,}010 & 0{,}012 & 0{,}061 & 0{,}000 & 0{,}007 & 0{,}064 \\ -0{,}013 & 0{,}002 & -0{,}016 & 0{,}000 & 0{,}006 & -0{,}001 & -0{,}006 \\ 0{,}008 & 0{,}001 & 0{,}001 & 0{,}007 & -0{,}001 & 0{,}002 & 0{,}013 \\ 0{,}064 & 0{,}014 & 0{,}011 & 0{,}064 & -0{,}006 & 0{,}013 & 0{,}100 \end{pmatrix} \quad (5)$$

The maximum eigenvalue of this matrix is λ=0.2031. This value corresponds to the eigenvector:

$$L=\begin{pmatrix} 0{,}512 \\ 0{,}068 \\ 0{,}213 \\ 0{,}482 \\ 0{,}072 \\ 0{,}083 \\ 0{,}666 \end{pmatrix} \quad (6)$$

The weighting factors α_i are proportional to the squares of the components of this vector: $\alpha_1 = 0{,}262;\ \alpha_2 = 0{,}005; \alpha_3 = 0{,}045; \alpha_4 = 0{,}232; \alpha_5 = 0{,}005; \alpha_6 = 0{,}007; \alpha_7 = 0{,}444.$ Thus, an integral assessment of the level of digitalisation development in Ukraine is as follows: $W(t) = 0{,}262y_1 + 0{,}005y_2 + 0{,}045y_3 + 0{,}232y_4 + 0{,}005y_5 + 0{,}007y_6 + 0{,}444y_7.$ The values of the integral assessment for 2014-2022 determined using this equation are shown in Table 2.

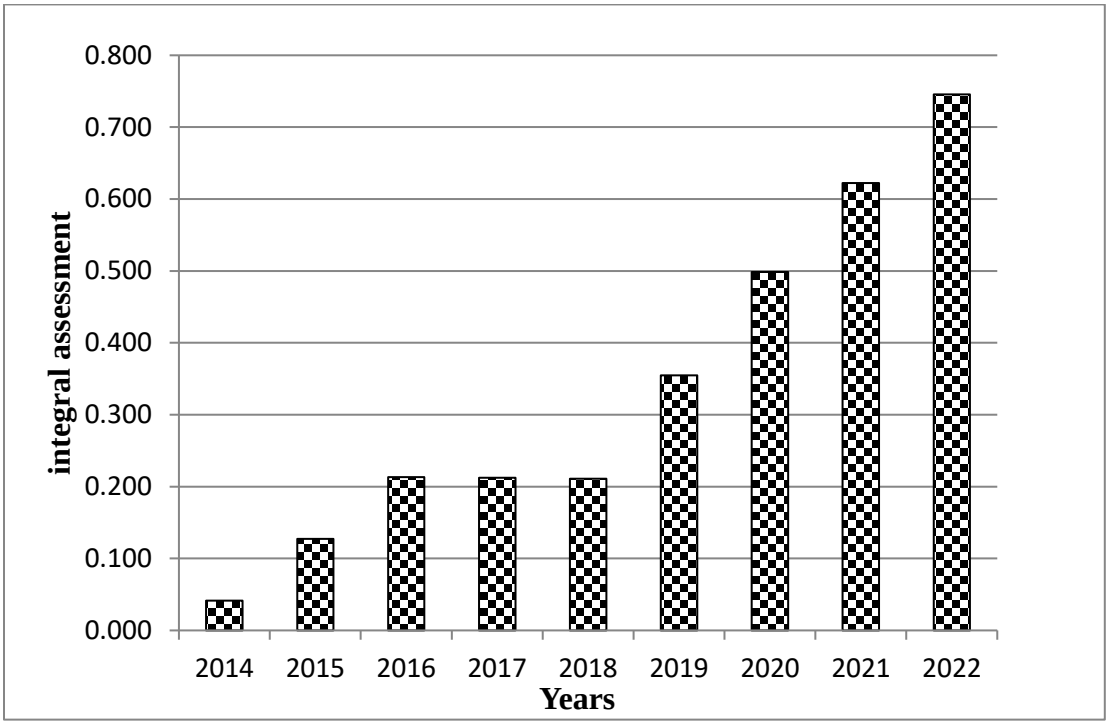
Table 2 Comprehensive integral assessment of the level of e-government development as an element of digitalisation in Ukraine

The year	2014	2015	2016	2017	2018	2019	2020	2021	2022
Integral assessment	0,041	0,127	0,213	0,212	0,211	0,355	0,499	0,622	0,746

Source: author's own research

The dynamics of this integral assessment is shown in Figure 1.

Figure 1: An Integral Assessment of the Level of E-Governance Development in Ukraine (2014-2022)



Source: author's own research

Three periods can be distinguished in the dynamics of the integral assessment: in 2014-2016, the assessment increased, from 2016 to 2018 it remained virtually unchanged, and from 2019 to 2022 it showed a significant increase.

4.2. Integral assessment of the level of development of the agri-food sphere in Ukraine

Digitalisation in the agricultural sphere is fundamentally changing the approach to the collection, processing, storage and use of information data, reducing production costs and increasing productivity, and hence profitability. With the development of innovative technologies, Ukrainian business entities in the agribusiness system are gradually digitising their operations. The first stage is the spontaneous digitisation of information, which gradually forms a large array of data in the form of BigData. The second stage is the process of systemising and

structuring data. The problem with the second stage is that it becomes impossible to work with them for a certain period of time. It is only with the transition to the third stage of BigData grouping that agricultural enterprises have the opportunity to catch up with the latest global trends in technology. The fourth stage is a complete digital transformation of agribusiness, which is something all agricultural producers should strive for. Conducting business in a purely digital format will allow farmers to maintain electronic document management, conduct business negotiations online and work freely without being tied to an office. The last stage of digitalisation cannot be achieved without gradual work on data conversion. However, one of the main barriers to the development of Ukraine's digital economy is the digital divide, which hinders this development by restricting agricultural producers' access to technologies, competencies, digital production and interaction tools. The technology gap is characterised by the lack of widespread adoption of high-speed Internet technologies. The level of access to 4G mobile Internet in rural areas is one of the lowest in Europe, at around 66%.

In order to quantify the impact of digitalisation on the development of the agri-food sector, we will determine the correlation coefficients between the integrated assessment of e-government development as an element of digitalisation and the integral assessments of the volume of food industry products sold, sales of basic food products in the retail network of enterprises, and indicators of environmental protection and preservation related to the agri-food sphere. The integral assessment of the volume of food industry products sold is determined on the basis of primary statistical indicators of meat and meat products production, fruit and vegetable processing and preservation, oil and animal fats production, dairy products production, flour and cereals production, starches and starch products production, bread, bakery and flour products production. The integral assessment of sales of basic food products in the retail network of enterprises is determined on the basis of primary statistical indicators of sales of meat and poultry (fresh and frozen), smoked meat, salted meat and sausages, rennet, processed and fermented cheese butter, eggs, vegetable oil, sugar, bakery products (except confectionery), flour confectionery products, sugar confectionery products (including ice cream), flour, cereals, pasta, fresh vegetables, fresh fruit, berries, grapes, nuts, processed vegetables and fruits (2024). The integral assessment of environmental protection and preservation indicators is determined on the basis of primary statistical indicators of pollutant emissions, carbon dioxide emissions, capital

investments in environmental protection and current environmental protection costs, with each of these indicators considered for both agriculture and the food industry. The weighting of these indicators in the integrated estimates is determined by the modified principal component method, which ensures the objectivity of the estimates.

Let us denote the obtained integral estimates of the volume of food industry products sold, sales of basic food products in the retail network of enterprises, and indicators of environmental protection and preservation related to the agri-food sector as W_1, W_2, and W_3, respectively. The values of these integral estimates in the retrospective period of 2014-2021 are shown in Table 3.

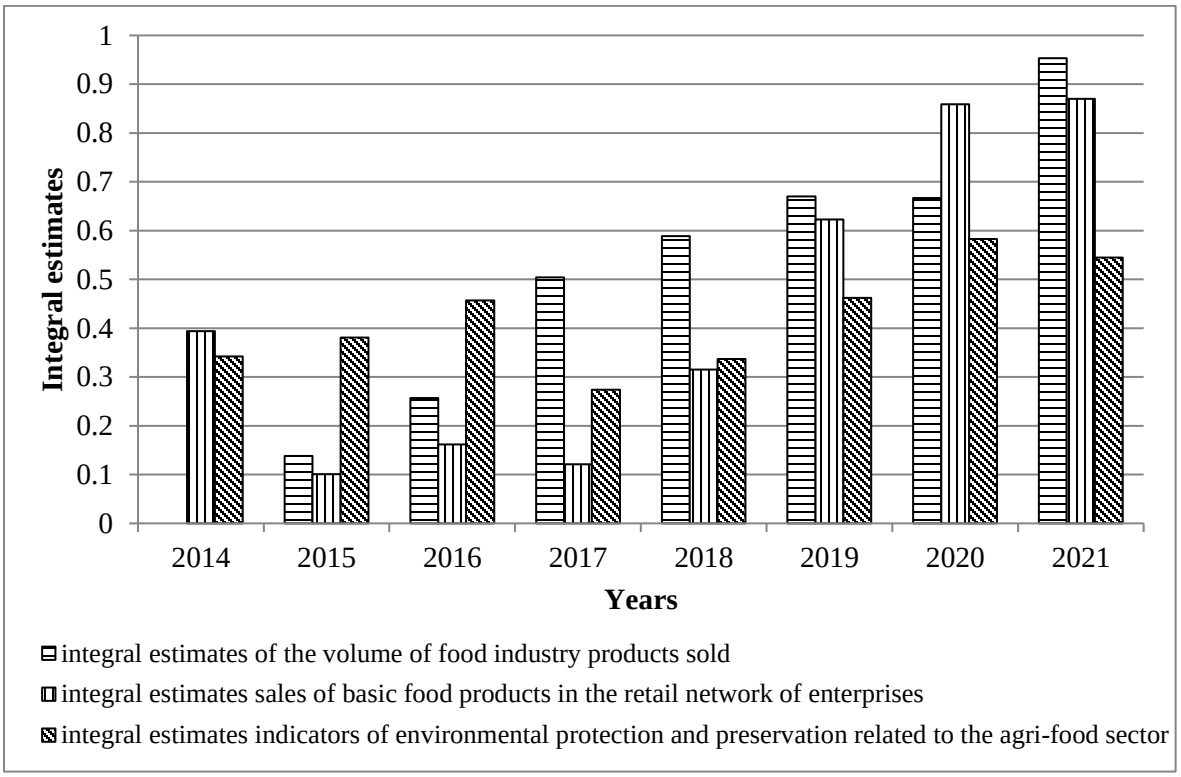
Table 3 Integral assessments of factors reflecting the level of development of the agri-food sphere in Ukraine

Assessment	Years							
	2014	2015	2016	2017	2018	2019	2020	2021
W_1	0,000	0,138	0,257	0,504	0,589	0,670	0,667	0,953
W_2	0,394	0,101	0,162	0,121	0,315	0,623	0,859	0,870
W_3	0,342	0,381	0,457	0,274	0,337	0,462	0,583	0,545

Source: author's own research

The dynamics of these integral assessments is shown in Figure 2.

Figure 2: Integral assessments of factors reflecting the level of development of the agri-food sphere in Ukraine (2014-2022)



Source: author's own research

4.3. Assessment of the impact of digitalisation on the development of agri-food sphere components

The correlation coefficients ρ_i between the scores W_i and the integral score W of the level of e-government development as an element of digitalisation are determined from equality:

$$\rho_i = \frac{\sum_{t=1}^{T}(W_i(t)-\overline{W_i})(W(t)-\overline{W})}{\sqrt{\sum_{t=1}^{T}(W_i(t)-\overline{W_i})^2}\sqrt{\sum_{t=1}^{T}(W(t)-\overline{W})^2}} \quad (7)$$

where $\overline{W_i}$ та $\overline{W}$ – are the average values of the integral estimates of W_i and W during the retrospective period, T – is the duration of this period.

The significance of these correlation coefficients is checked by the Student's criterion. The calculated value of this criterion is calculated by the formula:

$$t_i = \sqrt{\frac{\rho_i^2}{1-\rho_i^2}(T-2)} \quad (8)$$

The critical value $t_{kr}(\alpha; k)$ of this criterion is determined by the confidence level α, which we assume to be 0.95, and the number of degrees of freedom k=T-2. This value is 2.447. The correlation coefficient ρ_i is significant if there is an inequality $t_i > t_{kr}(0{,}95; T-2)$. The results of testing the significance of the obtained correlation coefficients are presented in Table 4.

Table 4 Verification of the significance of the correlation coefficients between the comprehensive integral assessment of the level of e-government development and the integral assessments of factors reflecting the level of development of the agri-food sphere in Ukraine

Integral assessment	Correlation coefficient ρ_i	Calculated value of the Student's t-test	The critical value of the Student's criterion	Conclusion
W_1	0,904	5,166	2,447	Significant
W_2	0,844	3,856	2,447	Significant
W_3	0,814	3,438	2,447	Significant

Source: author's own research

Thus, the significance of all correlation coefficients ρ_i is confirmed. Thus, there is a correlation between the integrated assessment of the level of development of e-government as an element of digitalisation and the integrated assessments of factors that reflect the level of development of the agri-food sphere in Ukraine.

In our opinion, the process of digitalisation has an active impact on all components of the agri-food sphere. In particular, the introduction of digitalisation in the food industry allows to increase production efficiency, introduce innovations in production processes, optimise logistics schemes for the supply of agricultural raw materials, effectively use scheduling models, ensure product quality control and compliance with standards, obtain up-to-date information on food demand and form a product range based on this information. In the food retail sector, digitalisation makes it possible to accumulate information on customer preferences to ensure the sustainability of the competitive position, organise online sales, use social media to advertise products, and use multimedia screens to organise customer interaction with brands. Implementation of digitalisation processes for environmental protection and preservation involves the use of digital tools and artificial intelligence to collect data on the state of the

environment, accumulate the information received, analyse it, forecast trends in environmental changes, and assess the likely environmental impact of strategic development projects.

5. Conclusion

The innovative development of the country's agri-food sphere requires the active use of information and communication technologies. The digitalisation process makes it possible to ensure efficient, transparent and sustainable development of this industry. An important element of digitalisation that significantly improves the quality of economic process management is e-governance.

The article develops a methodology for an integral assessment of the level of e-government development in Ukraine, which uses the indices of online services, human capital and e-participation, defined by the Department of Economic and Social Affairs of the United Nations Secretariat, and indicators of the spread of modern means of communication among the population. The peculiarity of this model is that it takes into account correlations between indicators, which is achieved by applying the modified principal component method.

The article reveals the existence of correlations between the obtained integral assessment of the level of development of e-government as an element of digitalisation and the integral assessments of factors reflecting the level of development of the agri-food sphere in Ukraine, namely, the volume of food industry products sold, sales of basic food products in the trade network of enterprises and indicators of environmental protection and preservation related to the agri-food sphere.

The main directions of influence of the digitalisation process on the components of the agri-food sphere of Ukraine are indicated.

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