

The object of the study is the activity of an agribusiness enterprise in using digital technologies. The problem of the methodology for assessing the effectiveness of using digital technologies by an agribusiness enterprise is solved. The following results were obtained:

– the author’s methodology for assessing the effectiveness using of digital technologies by an enterprise of AIC based on expert evaluation and a system of indicators was developed. The assessment results are interpreted in accordance with the matrix of intersection of the digitalization index and the effect of digital technologies from Outsider (0–0.25; <1) to Leader (0.95–1; ≥1);

– the obtained concordance coefficient (76 %, $\chi^2=41.9$) indicates high consistency of the expert group, consistency and qualitative assessment in the process of testing the methodology;

– testing of the proposed methodology in Atameken-Agro JSC was successful and showed the validity and convenience of this methodology. The agro-enterprise became the leader in 2023 with the indicators of digitalization level – 0.83 and the effect of using digital technologies – 12.5.

The above results are explained by assuming the possibility of using the expert judgment method to evaluate the efficiency of using digital technologies by an enterprise and applying a decision matrix based on two indices.

A particular feature of the results obtained is the development of a methodology for assessing the level of digitalization in three main areas and its application in combination with the assessment of the economic effect of digital technologies.

The proposed methodology can be used not only by enterprises wishing to evaluate the effectiveness of digital technologies but also by stakeholders

Keywords: digitalization, agribusiness, digital technologies, evaluation methodology, efficiency evaluation matrix, expert evaluation

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DEVELOPMENT OF A METHODOLOGY FOR ASSESSING THE EFFICIENCY OF AN AGRIBUSINESS ENTERPRISE IN USING DIGITAL TECHNOLOGIES

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1. Introduction

The agro-industrial complex is highly dependent on the level of material and technical, scientific and technological base of production. Therefore, the mechanisms and tools of digitalization determining the transition to the next stage of economic development – the digital economy – are relevant for the agricultural sector.

It is impossible to manage an agricultural enterprise that sets the task of optimizing production processes without

implementing digital transformation methods. The main goal is to achieve productivity, which means reducing costs, improving the quality, speed and accuracy of the information received. Advanced technologies include the use of sensors, robotics, Big Data, artificial intelligence, etc. and offer unique opportunities to improve production processes and management.

By the rating of digitalization of the agro-industrial sphere for 2023, the leading positions belong to the United States, Canada, Germany, Australia, and Israel [1]. In these

countries, holdings have already successfully integrated digital technologies not only in the sales system but also in agricultural production. Artificial intelligence algorithms are used to manage sowing and harvesting, land monitoring via satellites is carried out, methods of management of agricultural enterprises and machinery are introduced, the status of animals and plants is monitored, precision farming technology is developed, automated robotic systems are purchased, etc., as well as digital technologies are used in agricultural production.

The situation is different in developing countries. Agriculture is characterized by a long cycle of hypothesis testing and testing of innovative technologies. However, agrarians in developing economies are hampered not only by the time factor but also by the lack of independent testing sites, staff shortage, underdevelopment of basic information infrastructure. At the same time, agribusiness in such countries needs digital technologies, as they have an impact on increasing labor productivity, product quality and safety, contribute to resource efficiency, and reduce environmental impact. With the introduction of digital technologies in agricultural enterprises, it becomes possible to ensure stable development of the industry and provide the population with high-quality products.

At the same time, the digitalization of agribusiness cannot take place haphazardly at both macro- and micro-levels, as the costs incurred require a positive effect. It is important to accurately assess the effectiveness of digital technologies because they are costly and their results are difficult to predict. At the enterprise level, the introduction of methods for assessing the effectiveness of digital technologies leads to improved adaptability of agricultural producers to changing market conditions, increased competitiveness and sustainability, and better risk management.

The rapid pace of digitalization of production processes for the transition to smart manufacturing leads to the need to assess the effectiveness of using digital technologies for management purposes. Performing such diagnostics is necessary for managers to monitor and make management decisions. Thus, the topic of developing an assessment of the agribusiness enterprise's effectiveness in using digital technologies is necessary and relevant for research.

2. Literature review and problem statement

The introduction of digital technologies in business is always, first of all, a transformation towards innovative development. The paper [2] emphasizes that the transformation mechanism of agro-enterprises should be aimed at introducing innovative approaches to the modernization of technical and technological cycles of production and economic processes, leading to increased competitiveness in the agricultural market. Agreeing with this position, we note that digitalization is a priori aimed at economic efficiency of rational organization of the production process. However, the problem of assessing such efficiency in relation to the digitalization of agricultural production processes remains unresolved.

With the transition to the digital economy, scientific organizations, auditing and consulting companies, as well as scientists have developed a large number of methodologies to assess the digitalization level of enterprises, including in the aspect of efficiency.

The German National Academy of Science and Engineering, having researched organizations, has developed

the Industry 4.0 Maturity Index, determining at what stage of the digital transformation process an enterprise is [3]. All areas of the enterprise's activities are assessed for the possibility of digital transformation in accordance with Industry 4.0 by the level of: informatization, connectivity, visibility, transparency, predictability and self-correction. This methodology allows you to assess not so much the effect as the enterprise's potential for digital development. However, there are still unresolved issues related to the fact that this methodology allows assessing not so much the effect as the enterprise's potential for digital development. This requires a study on a more specific assessment.

The international consulting company Deloitte is the creator of the Digital Maturity Model, which allows determining the prospects for digital development in five areas of organization assessment: strategic, technological, production, structural and cultural. These areas include 28 categories and 179 evaluation indicators, determining the level of digital maturity of an enterprise [4]. Primary attention is paid to the company's strategy, including innovation prospects, based on which a business model with production and technological processes is developed. Thus, the methodology for assessing digital maturity is of a forward-looking nature. This approach can be used by large enterprises for assessment, but is time-consuming to collect baseline indicators and cumbersome in calculations. Therefore, Deloitte's digital development perspectives are assessed for country comparisons rather than used directly by enterprises.

KPMG International Corporation is the developer of Digital Business Aptitude, which establishes a set of indicators for key areas of enterprise activity in the fields of: management, strategy, digital capabilities, main processes of digital transformation, resource and technological flexibility [5]. Based on the assessment results, a circular matrix is created, reflecting the company's data and industry averages. This methodology is also focused mainly on digital capabilities, as the digital capabilities of the organization as a whole are assessed. But what remains unresolved is the evaluation of digitalization results, which is essential for agribusiness.

The international audit company PwC has developed the concept of "Digital Champions", which allows identifying the sources of digital priorities, including: cooperation with customers, production activities, technological component and personnel [6]. The analysis of the concept showed that the assessment is carried out in relation to the potential of digital transformation of the enterprise according to the following positions:

- skills and competencies in the digital economy;
- availability of digital transformation of production processes and services provided;
- use of platforms and digital technologies in interaction with customers.

So, this assessment methodology is carried out through the identification of risks in the absence of digitalization, but there is no component of the actual production effect.

The above methodologies can be recognized as detailed and justified for assessing the use of digital technologies and its changes (transformation), but the economic effect as fundamental in assessing the enterprise effectiveness is not expressed.

There is no generally accepted methodology for efficiency assessment in the economic scientific community, so the topic is a subject of scientific discussions. Classical approaches to determining efficiency can be distinguished:

– the method of determining efficiency by the ratio of the obtained effect and the amount of incurred costs [7]. In this approach, the greatest efficiency is defined as the greatest result per unit of cost (with a positive value). This method can be included in the evaluation methodology, as it reflects a specific result, but should be complemented with other evaluation methods based on production indicators;

– efficiency as a degree of achievement of predetermined goals (effectiveness) [8]. In this case, the efficiency assessment is relative. The reason for this may be formally or incorrectly set goals, including underestimation/overestimation of capabilities. A way to overcome these difficulties can be the use of integral indicators;

– efficiency as a measure of disclosure of the organization's potential [9]. In this methodological approach, in order to achieve the best result, the resources of the enterprise microenvironment are evaluated, but they should be supplemented with data on results.

The paper [10] notes that when evaluating innovation activities in agribusiness, which, in fact, is digitalization, effectiveness is most often calculated by the ratio of available results to the cost of innovation. Indeed, meaningful financial resources allocated to digitalization in agribusiness should pay off. But the main problem in assessing the economic efficiency of innovation activities is the optimality of resource allocation between agro-production processes and economic activities. A way to overcome it may be to conduct a comprehensive efficiency evaluation at each stage. The study [11] emphasizes that when assessing the effectiveness of the innovation activity of agro-enterprises, various systematic approaches are often used, including the balanced scorecard method and the cost method, which are based on economic profit taking into account the opportunity costs of the enterprise. Agreeing with this position, we add that the application of these analytical models allows emphasizing the factors that most affect the result. As a universal criterion, the market value of the enterprise can be used, and by assessing the sustainability of financial results, it is possible to calculate the risk level of investment in digitalization, as well as the potential profitability of the enterprise. The disadvantage of uneven cash flows can be leveled by adjustment coefficients.

The most common approach in efficiency evaluation is to form goals and indicators of their achievement at the time of making a decision to implement digital technologies [12]. The difficulty of using this approach is that its theoretical component is poorly studied. This approach was used in [13], showing that after the implementation of a digital product, indicators are tracked over time intervals. If the targets are achieved within the set timeframe, this indicates the right choice of a digital product and the effectiveness of the implementation process. But there are still unresolved issues: there is no systematized toolkit, the application practice does not have sufficient experience to form a set of outcome indicators and determine their threshold value, so it is impossible to unambiguously determine the objective effectiveness of such decisions.

In recent years, both approaches have been used together, leading to a better result. The development of an integral indicator for evaluating the efficiency of digitalization in industrial processes has a classical approach using the Overall Equipment Effectiveness (OEE) indicator [14]. The calculation is done by multiplying three coefficients: availability, productivity and quality. Availability considers temporary losses due to equipment downtime and is revealed by dividing the line operating

time by the labor time stock. Productivity determines the loss of speed during an operation and is calculated by dividing the speed on the production line by the set speed (or the ratio of the number of products manufactured by the maximum goods produced on the line). Quality is a parameter that specifies the size of losses in the manufacture of substandard products and is determined by dividing the number of good products by the total number of products. This method is suitable for agribusinesses, but does not take into account the efficiency of digital technologies that are not related to production. All this suggests that it is advisable to conduct a study on developing an efficiency assessment that integrates the production and related economic activities of an agribusiness enterprise.

The paper [15] proposes a methodology that integrates the assessment of the effects of digital agro-technologies by determining production efficiency, biological, economic, environmental and social efficiency. The problem is that, despite the wide coverage of agribusiness effects, the integral result of this methodology significantly “dilutes” the economic effect, which is preferential for agribusiness.

The work [16] formed a cost accounting method, considering all types of agro-industrial production costs, as well as an assessment of efficiency in relation to their sources. But the study does not fully assess the benefits of introducing digital technologies in the organizational activities of enterprises. This suggests that it is advisable to include not only the cost method in the valuation methodology.

The study [17] highlights the method of efficiency assessment based on risk minimization, assuming the accuracy and completeness of the assessment of the organization's available risks, and the degree of its readiness to work under uncertainty conditions. However, this method is difficult to implement in practice as it requires the construction of cumbersome mathematical and statistical apparatus.

With the development of computer science, it became possible to use Agent-based computational economics (ACE) models. The work [18] highlights simulation modeling as one of the most common methods in this area. This method uses large computing power and allows forecasting the effects of introducing any technology under uncertainty conditions. Most of the models combine components, variables and parameters, functional dependencies, constraints and objective functions. Despite its flexibility, this method has the disadvantage that the modeled abstractions may completely or partially mismatch with real agricultural production.

Thus, quantitative, probabilistic and qualitative methods are used to assess the efficiency of digital technology use by enterprises. But integral methods, including methods of different classification groups, are more in demand. In general, calculating an assessment of digitalization effectiveness is quite difficult, due to the influence of many factors on the organization. It can be concluded that at present the methodology for assessing the effectiveness of using digital technologies by agribusiness enterprises remains an unsolved problem, which requires theoretical and methodological development to obtain the most accurate economic assessment of efficiency in practice.

3. The aim and objectives of the study

The aim of the study is to develop a methodology for assessing the effectiveness of an agribusiness enterprise in using digital technologies.

To achieve this aim, the following objectives are accomplished:

- to propose and substantiate the main steps of the methodology for assessing the effectiveness of using digital technologies in agribusinesses;
- to perform expert testing for assessing the efficiency of an agribusiness enterprise in using digital technologies;
- to test the developed methodology for assessing the efficiency of digital technology utilization at agribusinesses.

4. Materials and methods

The object of the study is the activity of an agribusiness enterprise in using digital technologies.

The hypothesis of the study: based on expert evaluation and a system of indicators, it is possible to develop an objective methodology for assessing the effectiveness of an agribusiness enterprise in using digital technologies.

The study assumes that the assessment of the digitalization level and the effect of digital technologies can be combined into a final efficiency assessment using a matrix.

The study adopts the simplification that the digital transformation of an agribusiness starts when an appropriate strategy is adopted, whereas in reality it may occur earlier as a result of random decisions.

This study used the methods of analysis, generalization and differentiation, as well as expert evaluation and concordance methods.

The list of indicators was created taking into account the principle of sufficiency and completeness on the basis of international approaches used in assessing the degree of digitalization by global consulting and auditing organizations. The clustering of indicators was established thanks to the studies of the world's leading organizations [6], which have successfully implemented the transition to digitalization of business processes in different countries.

When assessing by ranking, the reliability and consistency of expert opinions were analyzed. To determine how consistent the opinions of the group experts are, the concordance coefficient was used. To determine the quality of expertise, after calculating the concordance coefficient, its relevance was defined using Pearson's test.

Information for calculation by the presented methodology was taken from available data sources: accounting reports, financial and economic reports of agro-industrial enterprises and other information available on the official website of the enterprise.

According to the methodology, the list of indicators to assess the digitalization level of an organization may consist of quantitative and qualitative indicators in accordance with the context of statistical analysis. The integral indicator is calculated from its constituent private indicators that are commensurate with each other and in the same format. In this regard, raw data are standardized by converting them into dichotomous values. Official statistical data do not contain the necessary amount of retrospective data that could help to analyze and standardize the selected indicators, so expert assessment is made on the basis of real and potentially possible values, and thresholds of qualitative indicators are determined.

Data processing was performed using Statistica 12 software (France).

5. Research results on the development of a methodology for assessing the effectiveness of digital technologies in agribusinesses

5.1. Proposal and substantiation of the main steps of the methodology for assessing the effectiveness of using digital technologies in agribusiness

Table 1 illustrates the main steps of the proposed methodology.

Table 1

Steps in the methodology for assessing the adoption of digital technologies

Step I	Step II	Step III
Preparation	Analysis	Result
<ul style="list-style-type: none"> – Determine the level of application of digital technologies; – parameters determining the economic effect of digitalization; – sources of information for the indicators 	<ul style="list-style-type: none"> – Calculation of the integral index of digitalization level; – calculation of indicators of priority areas for the introduction of digital technologies; – calculation of the economic effect of digitalization 	Analyzing the obtained data using the efficiency evaluation matrix

Given the duration of the digitalization process, as with any innovation project, it is necessary to determine the effect at each stage of project implementation (Table 1) in order to adjust it. At the same time, the level of digitalization may change over time. At the preparation step, the level of application of digital technologies and the parameters determining the economic effect of digitalization are identified, and the sources of information for the selected indicators are searched. At the analysis step, the integral indicator of the digitalization level and indicators of priority areas for digitalization are calculated, and the economic effect of digitalization is determined. At the last step, the obtained data are analyzed using the specified efficiency assessment matrix.

The main method in the structure of the proposed methodology is the method of expert evaluations. Determination of the level of experts' competence is carried out according to (1):

$$K = \sum_{i=1}^n \frac{P_i}{P_{\max}}, \tag{1}$$

where P_i – coefficient of expert compliance with criterion i ;

P_{\max} – maximum possible score for a criterion i , equal to 1.

Table 2 describes the rules for determining the level of expertise by the criteria taking into account the availability of skills and knowledge in AIC, digital literacy.

The presented criteria allow assessing the experts' characteristics that are significant for agribusiness digitalization. If the level of competence is higher than 0.85 from the calculation of the average of the criteria presented in Table 2, the expert is included in the group.

The representativeness of the expert group was determined by (2):

$$R = \frac{1}{n} \sum_{i=1}^m k_i, \tag{2}$$

where n – number of experts.

Table 2

Expert selection criteria

Block	Criterion	Compliance ratio
1	Specialized education in agro-industrial complex, economics or information technologies	
	Secondary vocational education	0.5
	Higher professional education	1
	Additional higher education	1
2	Expert's experience	
	Up to 3 years	0.3
	4 to 6 years	0.5
	7 to 10 years	0.7
	Over 10 years	1
3	Completion of a professional development program in the field of digital transformation	
	Availability	1
	Absence	0
4	Activities related to agro-industrial complex and (or) digital technologies	
	Availability	1
	Absence	0

The specific weight was determined from the results of the expert group's evaluations according to (3):

$$V_i = \frac{\sum_{j=1}^m Y_{i,j}}{\sum_{i=1}^n \sum_{j=1}^m Y_{i,j}}, \tag{3}$$

where m – number of evaluation indicators;

$Y_{i,j}$ – specific weight of indicator j according to the ranks given by expert i .

The cumulative sum of specific weights should not be higher than 1 in each group.

The economic effect (E) of using digital technologies is calculated according to (4):

$$E = \frac{\sum \Delta G_t}{\sum C_t}, \tag{4}$$

where ΔG_t – increase in results when implementing digital technologies (value terms);

C_t – cost of implementing digital technologies.

Calculation of the integral digitalization index of an agro-industrial enterprise is made by determining the weighted average value of group indicators according to (5):

$$D = \sum S_j (\sum I_j \times k_i), \tag{5}$$

where I_j – value of digitalization indicators in direction j ;

k_i – weight coefficient of indicator i of the priority area;

S_j – specific weight of direction j in the structure of the integral index.

Fig. 1 shows the order of calculating the indicators.

Table 3 shows the developed matrix that evaluates the efficiency of using digital technologies and helps to interpret the resulting integral indicators.

Table 3

Matrix for assessing the efficiency of agribusinesses in using digital technologies

Digitalization index	Effect of using digital technologies	
	<1	≥1
0–0.25	Outsider. Lack of application of digital technologies. It is necessary to make a managerial decision on implementing the digital economy in agribusinesses	Starter. The first stage of digital technologies use: there is an effect from their introduction, a small degree of digital transformation with the potential for development
0.25–0.50	Stagnant. Insignificant use of digitalization tools without a pronounced effect. Digital potential should be reviewed, other approaches and areas of digital development can be introduced	Developing. Insignificant use of digitalization tools with an effect from their implementation. There is potential for further growth
0.50–0.75	Resourceful. Active implementation and use of digitalization, without maximizing impact. Digital capacity can be increased by implementing optimal versions of digital technologies	Inertial. Active implementation of digitalization and its use in the organization, bringing good economic effect. There is potential for development
0.75–0.95	Catching up. Digital technologies are the main tool for agribusiness development, but are not fully utilized. There is a potential for digital transformation when optimizing the use of existing digital technologies, taking into account updates	Third leader. It functions under the digital economy principles, but its development potential is already insignificant. It is necessary to search for new areas of development
0.95–1	Second leader. Functioning under the digital economy principles. Investments in digital development no longer lead to increased profits, it is necessary to search for new areas of development	Leader. It functions under the digital economy principles, but there is no longer potential for development. It is necessary to search for trends among the latest developments, taking into account foreign experience

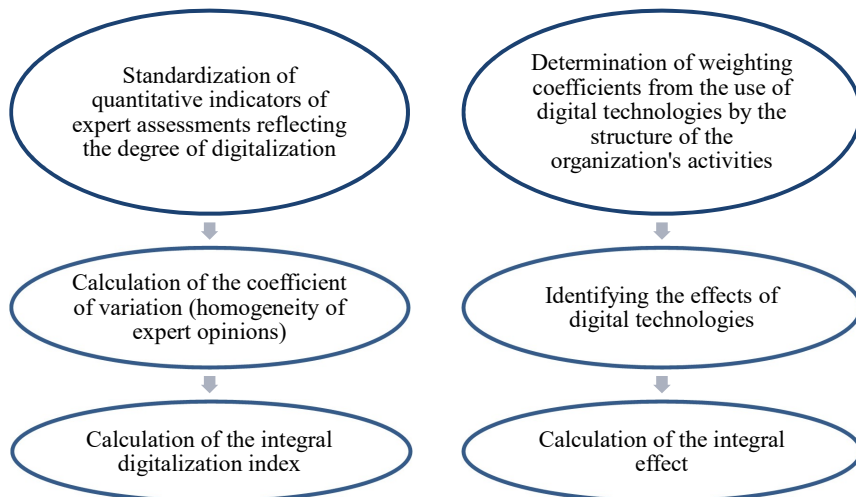


Fig. 1. Stages of calculating the indicators of the analysis step

With the digitalization index from 0 to 0.25, depending on the indicator of the effect of digital technology use, an agribusiness can be characterized as “Outsider” or “Starter”. If the effect is less than one, there is a lack of application of digital technologies, which requires a managerial decision on implementing the digital economy in the agro-enterprise. If the effect is equal to or greater than one, the agribusiness is assessed as “Starter”, i.e. it is at the first stage of using digital technologies. In this case, there is an effect from their implementation and a small degree of digital transformation with the potential for development.

With the index in the range of 0.25–0.50, agribusiness can be characterized as “Stagnant” (the effect is less than 1) and “Developing” (the effect is equal to or exceeds 1). In the first case, there is insignificant use of digitalization tools without a pronounced effect, which requires a review of the digital potential and the introduction of other approaches and areas of digital development. In the second case, there is insignificant use of digitalization tools with an effect from their implementation, and there is a potential for further growth.

If the digitalization index is greater than 0.50 but less than 0.75, then the agro-enterprise in the evaluation of the activity on using digital technologies can be “Resourceful” or “Inertial”. The first option takes place when the effect of digitalization is less than one. There is an active introduction and use of digitalization without maximum return, but the digital potential can be increased by introducing optimal versions of digital technologies. The second option takes place when the effect is equal to or greater than one. There is an active implementation of digitalization and its use in the organization with good economic effect and development potential.

“Catching up” type of agribusiness efficiency in using digital technologies is diagnosed by a combination of the digitalization index in the range of 0.75–0.95 and the effect of using digital technologies less than one. Digital technologies are the main tool for the development of such agribusinesses, but they are not fully utilized. There is a potential for digital transformation when optimizing the use of existing digital technologies with updates.

The top of efficiency is covered by three leaders. The first and second leaders have a digitalization index approaching one. The first leader demonstrates the effect of using digital technologies equal to or greater than one and operates under the digital economy principles, but there is no longer potential for development. Such an agribusiness needs to search for directions among the latest developments, taking into account foreign experience.

The second leader with an effect of less than one functions under the digital economy principles. Investments in digital development no longer lead to increased profits, which requires the search for new areas of development.

The third leader lags behind the other leaders in terms of the digitalization index but has a high effect of using digital technologies. Agribusinesses with this assessment function under the digital economy principles, but the potential for development is already insignificant. It is necessary to search for new areas of development.

Overlaying the final indicators for assessing the level of digitalization and efficiency of digital technologies use at an agro-enterprise on the matrix allows you to qualitatively determine the obtained result and strategic direction for making further management decisions in this area.

5.2. Expert testing to assess the effectiveness of an agribusiness enterprise in using digital technologies

10 competent experts participated in testing the proposed methodology. Experts’ competence was assessed as high (Table 4).

Table 4

Determination of experts’ competence

Indicator	Expert										Representativeness (coefficient)
	1	2	3	4	5	6	7	8	9	10	
Expert competence (coefficient)	1	1	1	0.92	0.87	1	1	1	1	0.92	0.97

As can be seen from Table 4, the representativeness of the expert group was confirmed, as the overall representativeness coefficient amounted to 0.97. It should be noted that a high representativeness coefficient is also observed for each expert separately, indicating high-quality sampling of the expert group.

Weighting coefficients were determined by ranking the data in each priority area by degree of importance. As a result of the data obtained during ranking, the weighting coefficient for each indicator was calculated (Table 5).

Table 5

Selected indicators and their weighting coefficients

Indicator	Unit of measurement	Weighting factor
Production		
Share of investment in digitalization	%	0.28
Number of in-house digital developments	Un.	0.08
Goods supply monitoring system	Yes – 1, no – 0	0.22
Electronic business process management system	Yes – 1, no – 0	0.13
Share of digital technologies in the total number of technologies	%	0.23
Workplaces equipped with the Internet (specific weight)	%	0.09
Personnel		
Share of professionals with digitalization competencies	%	0.51
Information technology support unit	Yes – 1, no – 0	0.22
Expenditures on purchase of digital technology labor tools (specific weight)	%	0.26
Cooperation		
Share of online sales	%	0.21
Electronic CRM system	Yes – 1, no – 0	0.50
Share of digital contracts in the total number of contracts	%	0.50

According to Table 5, the experts assigned the highest weight of all indicators to the share of professionals with digitalization competencies (0.51) and the share of digital contracts out of the total number of contracts (0.50). The share of investments in digitalization (0.28) and the share of expenditures on purchase of digital work tools (0.26) ranked second.

The final data of standardization of quantitative indicators to create an integral characteristic of digitalization level assessment are described in Table 6.

Table 6
Standardization of quantitative indicators of digitalization level

Indicator	Standardization
Investment in digitalization, %	<24=0, ≥24=1
Number of own digital developments, units	<4.3=0, ≥4.3=1
Digital technologies in the total number of technologies, %	<92=0, ≥92=1
Workplaces equipped with the Internet, %	<57=0, ≥57=1
Professionals with digitalization competencies, %	<48=0, ≥48=1
Expenditures on purchase of digital labor tools, %	<3=0, ≥3=1
Online sales, %	<61=0, ≥61=1
Digital contracts, %	<77=0, ≥77=1

The standardization method (Table 6) solved the problem of differences in the way the indicators are measured, as they are translated into dichotomous. This ensures a normal distribution.

Official statistical data do not contain the required amount of retrospective data that would help to analyze and standardize the selected indicators, so an expert assessment of normative values for each indicator was made. If the value exceeds the threshold value, such indicator is assigned 1, if the value is below – 0. Variation analysis was carried out and the nature of variability of the studied indicators was revealed.

5. 3. Testing of the developed methodology for assessing the efficiency of digital technology use at an agro-enterprise

Testing of the methodology was carried out by the data of the agro-enterprise Atameken-Agro JSC. The results of calculating the digitalization level of Atameken-Agro JSC are presented in Table 7.

Table 7
Digitalization level of Atameken-Agro JSC in 2020–2023

Group of indicators	Specific weight	2020	2021	2022	2023
Production	0.4	0.30	0.48	0.41	0.68
Personnel	0.3	0.00	0.00	1.00	1.00
Cooperation	0.3	0.00	0.00	0.80	0.80
Digitalization index	1.0	0.12	0.19	0.70	0.81

As can be seen from Table 7, Atameken-Agro JSC has a steady growth in the digitalization index, ensured by the inclusion of measures for personnel development and interaction with counterparties in the company’s business strategy in 2022–2023.

Further, the coefficients of the economic effect of using digital technologies were calculated by the developed methodology (Fig. 2).

The results of assessing the Atameken-Agro JSC’s efficiency in using digital technologies are presented in Table 8.

Due to the growth of the digitalization index in 2020–2023 and a significant increase in the effect of using digital technologies in 2022 (2.6 times by 2021) and 2023 (3.2 times by 2022), Atameken-Agro JSC has quickly moved from the “Starter” position to “Third Leader”. So, there is a potential for development and transition to the first leader position.

The obtained result reflects the nature of the enterprise’s movement through the quadrants of the matrix in the proposed methodology. The transition to digital transformation

by the agro-enterprise in 2020 determines the optimality of choosing the period 2020–2024 for testing the methodology.

Table 8
Results of assessing the Atameken-Agro JSC’s efficiency in using digital technologies for 2020–2023

Year	Digitalization index	Effect of using digital technologies	Efficiency quadrant for using digital technologies
2020	0.12	1.9	“Starter”
2021	0.19	1.5	“Starter”
2022	0.70	3.9	“Developing”
2023	0.83	12.5	“Third Leader”

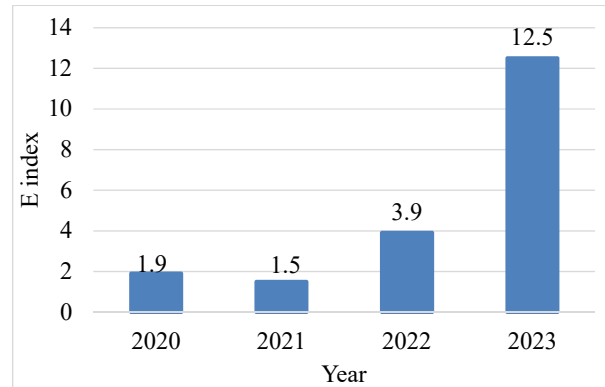


Fig. 2. Economic effect of using digital technologies at Atameken-Agro JSC for 2020–2023

6. Discussion of the results of developing a methodology for assessing the effectiveness of digital technologies in agribusinesses

Given the duration of the digitalization process, as with any innovation project, it is necessary to determine the effect at each stage of project implementation (Table 1) in order to adjust it. At the same time, the level of digitalization may change over time.

The preparation step allows determining the initial parameters needed to analyze the indicators within groups and integral characteristics. Efficiency assessment using the methodology involves determining the current digitalization level of the enterprise, as well as what economic effects have been achieved with the introduction of digital technologies.

Determining indicators for assessing the level of digitalization, which will help to define to what extent digital technologies are used. The set of indicators has a certain order of formation. Indicators are needed to identify the main parameters of digitalization of production management processes that maximize the economic result. Three priority areas of indicators can be identified: production technologies (“Production”), organizational structure and personnel management (“Personnel”), and interaction with customers and counterparties (“Cooperation”). Each area represents a set of activities related to the processes and agents of the micro- and macro-environment of the enterprise, the maximization of economic benefits in which becomes possible through optimization.

In order to establish a balance in cluster groups, parameters are used to reflect the degree of influence of these areas on the final result as a system of weights.

The specific weight of indicators in individual priority areas of digital activities is determined by expert assessment. When creating a group of experts, candidates are selected who best fit the following criteria:

- 1) education in the field of agro-industry, economics or information technology;
- 2) professional experience;
- 3) whether a professional development program in the field of digitalization has been completed;
- 4) whether the candidate's activities are related to the agro-industrial complex, digital technologies.

To determine the level of expert's competence in the issues under consideration, Formula 1 was used. The group is assembled from experts according to the criteria (Table 2), with a level of competence above 85 %, which is sufficient when assessing and making decisions in the digitalization of management processes of organizations operating in the determined sector. A representative group will be the one with an R coefficient above 0.67 (2).

The experts had to evaluate the indicators by ranking them according to their importance for each priority area, including setting the limits of standardization of numerical indicators. After that, the sum of the ranks of each indicator was identified (3). This allows analyzing both the degree of significance of each indicator and their comparison.

To determine the quality of expertise, it is necessary to calculate the boundaries of the concordance coefficient: $W < 0.4$ – low quality of assessment, $W > 0.7$ – good quality of expert assessment and high level of consistency of opinions. Then its relevance is determined.

Taking into account the duration and complexities arising when digitalization is implemented in the business model of an enterprise, including various mechanisms, approaches, and tools of the digital economy, it is important to consider the total costs to correctly assess how effectively digital technologies are used. For this purpose, we calculate the economic efficiency (E) when using digital technologies in the proposed methodology by (4).

The analysis step of the developed method consists in generalizing the results obtained and processing them into integral indicators for the degree of digitalization and the effect of its implementation (Fig. 1). From the ratio of indices of the digitalization level and the effect of using digital technologies at an agro-enterprise, it is possible to determine how effective the enterprise's activities in using digital technologies are.

After creating the list of indicators and their standardization, an integral index for the level of digitalization in each priority area is calculated, taking into account the identified weighting coefficients of the assessment results. So, a specific group weight is set in the areas "Production" – 0.4, "Personnel" – 0.3, "Cooperation" – 0.3. This choice is due to the largest share of the production sector in the structure of agro-industrial enterprises. In addition, the availability of indicators for production is higher. At the same time, the proposed methodology allows maintaining a balance in cluster groups in the analytical study of the main digitalization areas (5).

The final step is to determine where the enterprise stands by the level of digitalization compared to the resulting effect of the implemented digital technologies (Table 3).

The presented approach is comprehensive, which allows supplementing the available methods for assessing the digitalization of enterprises with the parameters of value analysis while ensuring the universality and flexibility of the assessment. The methodology also makes it possible to take into ac-

count the peculiarities of the agro-industrial complex industry and, if necessary, to adjust or supplement the parameters.

Testing of the developed methodology for assessing the effectiveness of using digital technologies at the agribusiness enterprise Atameken-Agro JSC was carried out.

The representativeness coefficient for the 10 experts was 97 %, indicating that the expert group was representative (exceeding 67 %) (Table 4).

Further, with the help of experts, the weight coefficients of the main priority areas were identified: production and technologies, organizational structure and personnel, cooperation with customers and counterparties (Table 5).

The obtained concordance coefficient (0.76) indicates high consistency of the expert group, consistency and qualitative assessment. The significance of the concordance coefficient was assessed using Pearson's test: the given significance level $k=11$, $a=0.05$, the value of $\chi^2=41.9$, which is higher than the table value – 19.7. So, with a 95 % probability, the result is significant and not a random value, the expert estimates are acceptable for use.

The first block of data (Table 5) relates to production technologies. This group consists of six indicators taking into account how digitalization affects the development of production: the share of investments in digitalization, the number of own digital developments (in the last 4 years), the goods supply monitoring system, the electronic business process management system, the share of digital technologies in the total number of technologies, and workplaces equipped with the Internet (specific weight).

The second group of indicators allows determining the influence of the human factor, as well as identifying the personnel potential for the introduction and development of digital technologies in the organization. It is often the direction that faces resistance from the staff. In the "Personnel" block, the specific weight was distributed by experts in such a way that the number of employees with digital competencies has the greatest impact on determining the digitalization level of the enterprise.

The third block of indicators reflects the customer focus of the agro-enterprise, the nature of communication with suppliers and consumers of goods.

The method of standardization of indicators was used (Table 6). The selected list of indicators is characterized by the absence of indicators of reversible influence, but individual characteristics are measured differently, and therefore it became necessary to bring the standardization of indicators into dichotomous.

Table 7 calculates the digitalization level of the Atameken-Agro JSC agro-enterprise. The enterprise has a good level of implementing digital resources in business processes across all production sites. Every year, starting from 2020, the agricultural holding introduces a large number of new digital technologies. At the same time, the company's developments in the field of innovation are focused on bio- and selective technologies. In 2021, an information technology department was introduced into the organizational structure of the agro-enterprise, which caused significant changes in the dynamics of the final digitalization level in 2022 and 2023 (6 and 7 times higher than in 2020, respectively). A slight decrease in the indicator for the "Production" group in 2022 is due to the increase in the total number of technologies in the enterprise, which reduced the share of digital technologies.

The results and costs of digitalization are reflected in the profit growth of companies. In this regard, the calculat-

ed effect should take into account the observed cumulative effect since the beginning of implementing digitalization in the enterprise. When a negative result of the organization's profit growth using digitalization is obtained, the indicator is equal to 0, but at the Atameken-Agro JSC agro-enterprise there is a non-linear growth of the effect of using digital technologies (Fig. 2).

The matrix for assessing the effectiveness of activities on using digital technologies, presented in the methodology, allows us to interpret the obtained calculated data and draw conclusions based on the obtained information on Atameken-Agro JSC (Table 8). Since the beginning of digital transformation for 4 years, the agro-enterprise managed to move from the quadrant "Starter" to "Third leader", indicating in general the effectiveness of activities on using digital technologies. The further development of Atameken-Agro JSC in digital transformation is business processes of production: the introduction of analytical systems of big data, robotics and artificial intelligence. In addition, due to the high level of digitalization, the company can occupy open market niches in the development of specialized programs for managing selective processes. The organization also has the potential to increase sales via the Internet, while marketplaces and other digital trading platforms can be used. However, this stage of the company's digital development necessitates the search for new areas of digitalization in the long term due to approaching the maximum level of the business life cycle.

There is a similar study [19], which proposes a diagnostic to measure the digital innovation of agricultural cooperatives based on comparison with industry indicators. This approach should be recognized as broader than our study, but the assessment of digital innovation itself is based on a smaller number of indicators, does not take into account the economic effect, and has no interpretation in the decision matrix. The advantages of our study are the universality and flexibility of the proposed values, which, if necessary, can be adjusted or supplemented with new input parameters, indicators, activities. The results of the efficiency assessment are interpreted using the developed matrix, which allows determining the current state of the digitalization process and the potential for its further development.

Limitations of the study. The determined indicators are not benchmarks and are used only to study the level of digitalization in the agro-industrial complex and test the developed methodology. With the expansion of research on the selected issues and increased availability of statistical data, the results may be transformed.

A shortcoming of the study is that the list of indicators is limited to official reporting, while increasing the availability and openness of data on enterprise digitalization could provide more accurate results.

The development of this study in the future could be carried out taking into account various areas in the structure of agroholding's activities, e.g. crop/livestock production or in a more fragmented differentiation: grain production, seed production, poultry production, etc. This would allow applying more precise management tools to each of the agroholding's activities but may cause difficulties in combining them into a common strategy. In addition, there may be difficulties in accessing more detailed data on the agroholding's operations for these purposes, especially if the enterprise does not provide for extended reporting.

7. Conclusions

1. The author's methodology for assessing the effectiveness of the agribusiness enterprise in using digital technologies based on expert evaluation and a system of indicators has been developed. The evaluation results are interpreted according to the matrix of intersection of the digitalization index and the effect of using digital technologies:

- Outsider ($0-0.25; <1$);
- Starter ($0-0.25; \geq 1$);
- Stagnant ($0.25-0.5; <1$);
- Developing ($0.25-0.5; \geq 1$);
- Resourceful ($0.5-0.75; <1$);
- Inertial ($0.5-0.75; \geq 1$);
- Catching up ($0.75-0.95; <1$);
- Third leader ($0.75-0.95; \geq 1$);
- Second leader ($0.95-1; <1$);
- Leader ($0.95-1; \geq 1$).

2. A group of experts competent in agribusiness and digital technologies with a representativeness coefficient of 97 % was selected for testing, which determined the weighting coefficients of indicators and their standardization. The obtained concordance coefficient (76 %) indicates high consistency of the expert group, consistency and qualitative assessment. The significance of the concordance coefficient was assessed using Pearson's test: the given significance level $k=11$, $a=0.05$, the value of $\chi^2=41.9$. So, with a 95 % probability, the result is significant and not a random value, the expert estimates are acceptable for use.

3. Testing of the methodology at the Atameken-Agro JSC agro-enterprise was successfully conducted and showed the validity and convenience of the developed methodology. The dynamics of the agro-enterprise digitalization level and the effect of using digital technologies for 2020–2023 showed a non-linear growth. Increased investment in digital technologies and the creation of an information technology support department in 2022 allowed the agro-enterprise to become a leader in 2023 with the indicators of digitalization level – 0.83 and the effect of using digital technologies – 12.5.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Data will be made available on reasonable request.

Use of artificial intelligence

The authors have used artificial intelligence technologies within acceptable limits to provide their own verified data, which is described in the research methodology section.

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