# FORMALIZATION OF THE OPTIMAL CHOICE OF THE ACTIVITIES OF AGRICULTURAL ENTERPRISES FOR THE IMPLEMENTATION OF INFORMATION AND COMMUNICATION TECHNOLOGIES

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# FORMALIZATION OF THE OPTIMAL CHOICE OF THE ACTIVITIES OF AGRICULTURAL ENTERPRISES FOR THE IMPLEMENTATION OF INFORMATION AND COMMUNICATION TECHNOLOGIES

**Ingram K.**
D.Sc. in Management, Lecturer, University of Applied Sciences, Vilnius, Lithuania;
ORCID: 0000-0001-9136-1896

**Diachenko O.**
D.Sc. in Public Administration, Professor, Odessa State Agrarian University, Odessa, Ukraine;
ORCID: 0000-0001-9670-2266

**Halytskyi O.**
D.Sc. in Economics, Professor, Odessa State Agrarian University, Odessa, Ukraine;
ORCID ID: 0000-0001-9549-7627

**Nitsenko V.**
D.Sc. in Economics, Professor, Ivano-Frankivsk National Technical Oil and Gas University, Ivano-Frankivsk, Ukraine;
e-mail: vitaliinitsenko@gmail.com
ORCID: 0000-0002-2185-034141
(Corresponding Author)

**Romaniuk M.**
D.Sc. in Economics, Professor, Vasyl Stefanyk Precarpathian National University, Ivano-Frankivsk, Ukraine.

**Zhumbei M.**
PhD in Economics, Associate Professor, Vasyl Stefanyk Precarpathian National University, Ivano-Frankivsk, Ukraine;
ORCID: 0000-0002-8883-4135

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## ABSTRACT

Methodological approaches that allow introducing effective management of an agro-company in conditions of risk, in particular, by optimal diversification of activities and analysis of results and directions of influence of information and communication technologies on management decisions in agribusiness have been developed. The level of relevance of the mathematical model and methods of analysis are increased using the approach of taking into account the uneven dynamics of indicators of digital competitiveness of the country. By the example of the projected reduction of the total land bank of leading Ukrainian agricultural holdings, it is proved that the latest information technologies stimulate the transition from the extensive to an intensive method of doing business and contribute to the growing role of information and communication technologies to increase the efficiency of enterprises. The mathematical model of the company's management has been improved and for the first-time methods of analysis that allow determining and optimizing the activities of agricultural holdings in a formalized way have been proposed. An improved application of the indicative method as a tool to increase the level of relevance of mathematical formalization is proposed. For the first time, it is stated that information and communication technologies are not only a management tool, but also a factor of strategic restructuring of the company. For the first time, it has been proved that the introduction of information technologies accelerates trends in the intensive development of agricultural holdings, in particular, in approaches to the formation of land banks. For the first time, using a practical example it has been shown that even the most diversified agricultural holdings need to improve the ratio of activity areas permanently, responding to external challenges. The proposed mathematical formalization can be applied in research and practical work. The use of the developed mathematical model allowed proving the possibility of effective distribution of activities of agro-holdings for future periods with relevant leveling of risks using a practical example.

**Keywords:** information and communication technologies, areas of activity, agricultural holdings, risks, mathematical model

**JEL Classification:** Q00, Q13, Q22

## INTRODUCTION

Ukrainian agricultural holdings are an example of the development of the latest mechanism for the formation of corporate culture in response to social, political and economic challenges. The weakening of the role of the state in the organization of agricultural production has contributed to the creation of these economic entities that are open to innovation, in particular, in the sphere of information and communication technologies (ICT).

## LITERATURE REVIEW

The role of ICT in neutralizing the risks of agribusiness was noted by the following researchers: Insha et al [1], Khirsa [2], Singh et al [3], Milovanovic [4], etc. A number of authors use mathematical approaches to the formation of risk management strategies. Modeling of catastrophic risk management in agriculture is considered, in particular, in [5]. The analysis of literature sources showed that especially important areas of ICT use to minimize risks are: short-term and long-term market forecasts, automation of management processes, structuring of business processes, development of electronic document management as a means to avoid routine, unnecessary costs and increase business efficiency, formation of a single source of information, effective preparation and consolidation of accelerating the decision-making process, monitoring the condition of the soil, Digital Transformation of the virtual workplace of the manager [6-8].

The underestimation of fixed assets of agricultural production is an example of the impact of irrelevant information that leads to incorrect management decisions, and which primarily concerns the main indicators: depreciation deductions, prime cost, financial result, profitability. Over the past ten years, fixed assets in agricultural production have been overvalued by only 43%, while in the industrial sector this indicator became 6.3 times bigger.

The use of modern corporate ICT provides a competitive advantage of effective management due to: the efficiency of data flow processing, increasing the productivity of management, increasing operational control of departments while ensuring transparency of their actions, complete awareness of management in making management decisions [9, 10]. Corporate ICT creates conditions for the simultaneous implementation of management strategies to achieve optimal values of key indicators: cost of production, structure and level of costs, profitability, etc. [11, 12].

## AIMS AND OBJECTIVES

Despite a large amount of research on the use of ICT in shaping the mechanisms of corporate culture, the definition and mathematical formalization of the optimal vector of management of agricultural companies are unsatisfactory and require further research.

The purpose of the article is the mathematical formalization of a new approach to the choice of effective management of the agricultural company in terms of risk, in particular, through optimal diversification of activities and analysis of the impact of information and communication technologies on management decisions.

## METHODS

Method of content analysis (systematization of management publications for the use of ICT in conditions of risk, directions of competitive advantage); economic and mathematical (determination of areas of activity in conditions of risk); time series method (forecasting the total land capital of the top 5 agricultural holdings).

## RESULTS

Significant fluctuations in the dynamics are a characteristic feature of the uneven implementation of information and communication technologies in Ukraine and, accordingly, the unevenness of their impact on the activities of domestic enterprises and industrial associations. For example, we noted a decrease in the indicator "Knowledge" by 15.4% during the time interval of observations conducted by WEF. Also, the fact that the overall indicator of Ukraine's digital competitiveness in 2018 was lower than the same indicator in 2015 (Fig. 1) is a characteristic feature of this inequality. That is, instead of a slow growth or at least stagnation, a considerable decrease of this indicator was observed.


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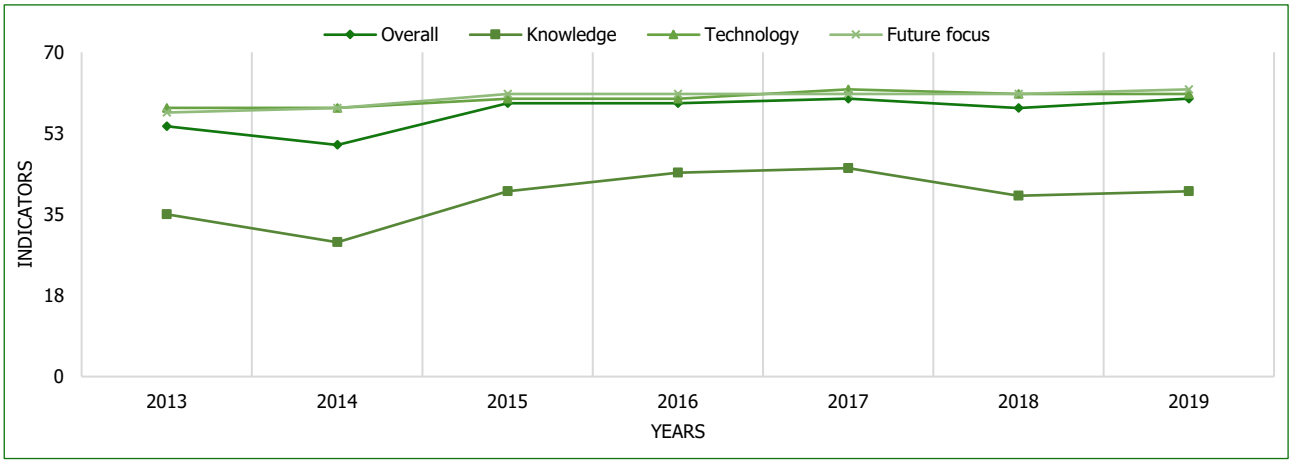


**Figure 1. Rating indicators of digital competitiveness of Ukraine.** *(Source: made by the author based on The Global Competitiveness Report WEF)*

Analysis of the dynamics of rating indicators of digital competitiveness of Ukraine presented in Fig. 1 preceded the next stages of the analytical study, for which time interval relative to projected changes in these indicators, which began in 2017 was chosen on the basis of the results of this stage (see Fig. 1).

This allowed avoiding information "noise", which is especially important when using the method of time series. According to the understanding of Box-Jenkins, in the mathematical formalization of the problem, these "noises" are factors influencing the abrupt changes in indicators of digital competitiveness, which, to some extent, correlate with the results of information and communication technologies in management.

Effective management of the company, especially agricultural companies, in conditions of risk, in particular, is associated with the use of ICT for a sound choice to diversify the activities of the enterprise. This is especially important for agricultural holdings because by definition, the control of the so-called "parent" company holding over the so-called "subsidiaries" is carried out also by determining their business activities and their accuracy and validity condition the economic effectiveness of management.

The optimal decision on the integrated direction of the business of a large agricultural enterprise is complicated by the fact that each of the agricultural enterprises simultaneously realizes several business areas (see Table 1 "Main activity").

**Table 1. Economic indicators of the top agricultural holdings of Ukraine.** *(Source: made by the author based on enterprise statistical reporting)*

| Company name | Number of employees, people | Product storage capacity, thousand tons | Revenue, million dollars USA | | Net income, million dollars USA | | The main activity |
|---|---|---|---|---|---|---|---|
| | | | years | | | | |
| | | | 2017 | 2019 | 2017 | 2019 | |
| Kernel | 12807 | 2500 | no data | 3992 | no data | 178.5 | sunflower oil, cereals, corn |
| UkrLandFarming | 20000 | 2700 | 658 | no data | -158.6 | no data | eggs, cereals, livestock |
| MHP | 28500 | 1100 | no data | 2056 | no data | 215.3 | chicken, meat processing, cereals |
| Agroposperis | 3328 | 520 | 322 | no data | no data. | no data | wheat, corn, sunflower |
| Astarta-Kyiv | 10000 | 550 | no data | 499.7 | no data | 1.9 | sugar, wheat, corn |
| Continental Farmers Group | 2400 | 387 | no data | no data | no data | no data | potatoes, seeds, cereals |
| Epicenter of Agro | 2765 | 1000 | no data | 1640 | no data | 130 | seeds, cereals, oilseeds |
| Harveast | 1800 | 74 | no data | no data | no data | no data | seeds, milk, compound feeds |
| IMC | 2100 | 554 | no data | 169.6 | no data | 7.3 | cereals, oilseeds, milk |
| Ukrprominvest Agro | 4600 | 125 | 227.3 | no data | no data | no data | sugar, livestock, flour |

This is due to the fact that, as practical experience shows, the risk of mono-commodity agricultural enterprises, regardless of their size, is much higher than for multi-commodity enterprises. Several areas of work of an agricultural enterprise allow, to some extent, to mitigate the impact of unforeseen risks, primarily weather ones, for a particular activity.

Each of the business lines of an agricultural enterprise has its own sets of risks. And, as the study shows, the company may even agree to a certain loss of an area for a certain period of time (often - the season) to preserve the infrastructure and professional staff in this area. But such losses must be offset by profits from other activities. In addition, the risks for large agricultural holdings are exacerbated by the fact that these companies create internally coordinated technological chains. Namely: the production of agricultural products, their accumulation and storage, transportation and sales. The coordination of these technological chains requires a high degree of management efficiency to avoid technological, reputational and economic losses, which were largely inherent to agricultural production in previous periods.

Obviously, given the increasing use of ICT to form the optimal vector of management of the company in terms of risk, agricultural enterprises must base their decisions on relevant mathematical formalization.

To form an effective set of actions to reduce risk, we used an adapted model, which was proposed in a set of scientific papers [13-15].

The following main mathematical representation was chosen according to [13]:

$$\emptyset(Q_1, Q_2) = \| Q_{bg} - Q_1 Q_2 \|_F = \| \hat{Q}_{bg} - vec(Q_1) vec(Q_2)^T \|_F = min \quad (1)$$

$$\{vec(Q_1^{opt}) = \sigma_1^{1/2} U(:1), f_i^f \to opt vec(Q_2^{opt}) = \sigma_2^{1/2} V(:1), f_i^f \to opt \quad (2)$$

$$Q_{bg} \in \nabla m \times n \quad (3)$$

$$m = m_1 m_2 \quad (4)$$

$$n = n_1 n_2 \quad (5)$$

$$Q_1 \in \nabla m_1 \times n_1 and Q_2 \in \nabla m_2 \times n_2 \quad (6)$$

where $Q_{bg}$ is a set of business strategies (so-called "basic") before the onset of crisis conditions due to risks. It is a set as it is a complex that includes strategies for certain areas of work $Q_j$conditions of which are $Q_j \in Q_{bg}$; $Q_j = \emptyset$; $Q_1, Q_2$ are competitive options for sets of business solutions to neutralize risks; mare risks for each of the activities of the agricultural enterprise; $m_1, m_2$ are risks for the first and second competitive options of management actions of the agricultural enterprise; $n$ is the number of activities of the agricultural enterprise; $n_1, n_2$ are the number of activities of the agricultural enterprise for the first and second competitive options for management actions of the agricultural enterprise; $f$ is the local set of risk factors for $i = 1 \dots m(n)$; $F$ is the general risk matrix; $T$ is the symbol of transposition of vectors by the method proposed in [13].

The concept of a general risk matrix $F$ in the presence of local sets of risk factors $f$, i.e. linear matrices, should be introduced, as some of the factors can affect several risks at the same time. This, in turn, requires the calculation of the multicollinear influence of these factors by the method [14].

Analysis of the literature shows that some risks of agricultural holdings are stochastic.

Calculation of the probability of stochastic risk for a particular business process for the selected target indicator can be made as follows:

$$\varphi = \int_{x_1}^{x_2} x * \gamma(x) dx \,/\, \int_{x_1}^{x_2} \gamma(x) dx \quad (7)$$

where $\varphi$ is the target indicator; $\gamma$ is the probability of stochastic risk in the interval 0… 1; $x$ is a variable parameter.

A practical example of the application of mathematical model (1)-(7) was forecasting the long-term distribution of activities for the agricultural holding PJSC "Myronivsky Hliboproduct" (hereinafter - MHP) for 2022 (see Fig. 2) according to the data presented on the manufacturer's website.

Conducting an analytical study, we included non-agricultural, but related areas, such as production of biogas, reinforced concrete structures and ready-mixed concrete and so on in the "other activities" of the holding (see Fig. 2). The problem


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was that there was a lack of data for detailed and relevant forecasting of these "other activities" using the presented methodology.

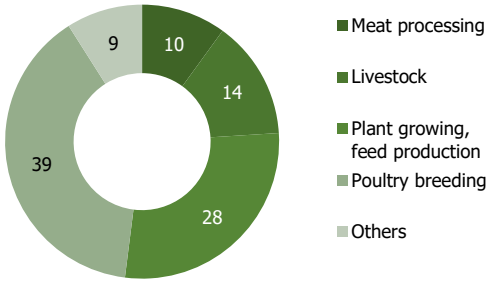


**Figure 2. Forecasting the activities of the MHP holding using a mathematical model of choosing the optimal business strategy for profit in terms of risk.** *(Source: made by the author based on enterprise statistical reporting)*

It should be added that MHP, whose activities were projected, and Kernel are the most diversified agricultural holdings in Ukraine, but, nevertheless, it, like other agricultural holdings, must constantly diversify its activities to minimize risks.

The basic group of parameters of impact on the risk of agricultural enterprises in Ukraine should be divided into subgroups that were identified in studies [14, 15]: natural, technological, political, legal, tariff, commercial, financial, social risks. The division into subgroups allows a more relevant way to analyze the impact of each of them without averaging the data of all these subgroups, which can lead to systematic errors. The analysis showed that agricultural holdings increase investment in digital technologies because the management sees by practical results that these investments can increase efficiency and effectiveness. Digital Transformation of business processes accelerates the formation of digital corporate culture, and the transition to digital thinking within the corporation contributes to qualitative changes in all processes - from management to production. The development of information and communication technologies significantly increases the competitiveness of Ukrainian agricultural enterprises and corporations in the world market. The cloud technology foundation is the most promising area of ICT [16-18]. This allows to reduce the cost of equipment and software, reduce the negative impact of the "human factor" on the management of agricultural holding data, increase the effectiveness of management actions of mobile staff, and attract foreign specialists for remote information support. The ability to manage the computational load according to the season is important from the point of view of optimization of administrative costs as seasonality is characteristic of agricultural production.

Agricultural enterprises, even farms, benefit from the competitive advantage of ICT. According to Forbes Ukraine, four agricultural holdings are included in the top 20 innovative companies in the country, in particular, MHP with an innovation index of 54.2, Nibulon with an index of 43.8 (see Table 1).

One of the winners, Kernel, for example, not only implements local IT projects for the management, but also conducts the largest ICT project in Ukraine #DigitalAgriBusiness. The #DigitalAgriBusiness project is general integrated automation of technological and management processes, which, of course, is determined by the quality of management of all areas of the holding.

The use of ICT, as the analysis shows, in addition to these benefits, increases efficiency in the following main areas: resource management; optimization of work and synergetic effect from the formation of the mechanism of corporate culture, reducing the routine component and promoting the creative approach of employees, increasing product quality and optimizing its storage.

Since agricultural production depends on the processes of transportation and storage of products, the formalized risk parameters are the degree and rate of wear of technical and technological equipment; energy costs, the rate of spoilage of products during transportation, the rate of spoilage of products during storage, the rationality of the rate of procurement of products and the level of compliance of these indicators with available storage capacity and transport capacity (due to a realistic assessment of transport resources), etc. The analysis shows that the deterioration of these formalized parameters is, in particular, due to difficulties in operational management, control and coordination of activities at certain stages of production, processing and transportation of products with insufficiently coordinated quantitative growth of production factors for all production processes. And the introduction of ICT, in particular, helps reduce these risk factors.

The analysis shows that the extensive development of agricultural enterprises by using the increased resource base does not always lead to increased profitability of the enterprise, because, in our opinion, the level of unmanageability is increased, reducing the effectiveness of management. The use of ICT contributes to the growing influence of intensive

factors inherent in modern corporate culture in management and, thus, increases the role of intensive factors in increasing the efficiency of enterprises. At the same time, the analysis of EBITDA of the surveyed agricultural enterprises showed that this indicator was significant for the leading agricultural holdings and correlated with the level of transparency, which in turn correlated with the level of ICT implementation.

Ukrainian agricultural holdings are becoming key players not only in the domestic but also in international markets. This is also an incentive for the management of holdings to pay special attention to both technical and technological re-equipment and the introduction of state-of-the-art ICT as this is a condition for the competitiveness of Ukrainian agricultural holdings in the world market.

The study found out that such a strategic area as the increase of the land bank, which was previously considered an integral part of the vertically integrated business model of the agricultural holding [19], ceases to play a decisive role. In a way, according to the experience of practical activities, each of the agricultural holdings is already implementing, more or less consistently, a program to optimize their economic performance with a certain change in approach to the formation of their land resources. As a result of the analysis, it was found that the land bank of Ukrainian agricultural holdings amounted to ~ 3600 thousand hectares in 2019, which is ~ 700 thousand hectares more than the result of this indicator in 2017. But, as it can be seen from Table 2, despite this increase, the land resources of large agricultural enterprises in recent years have a trend for stabilization and even reduction of land banks. The top 10 agricultural holdings are an example of this (see Table 2).

**Table 2. Dynamics of change of land banks of leading agricultural holdings, thousand hectares.** Note: * – expertly obtained data. *(Source: made by the author based on enterprise statistical reporting)*

| Company name | Years | | | | | |
|---|---|---|---|---|---|---|
| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020* |
| Kernel | 430 | 430 | 603 | 570 | 600 | 590 |
| UkrLandFarming | 654 | 605 | 605 | 560 | 560 | 550 |
| MHP | 360 | 370 | 370 | 370 | 370 | 370 |
| Agroposperis | 390 | 385 | 430 | 430 | 410 | 410 |
| Astarta-Kyiv | 245 | 250 | 250 | 250 | 210 | 590 |
| Total | 2079 | 2040 | 2258 | 2180 | 2150 | 2130 |

This conclusion does not confirm the conclusions of the association "Ukrainian Club of Agrarian Business", whose experts predicted the growth of the land bank of Ukrainian agricultural holdings to ~ 6250 thousand hectares in 2020 [20].

Specific indicators were calculated for comparative analysis of the effectiveness of corporate culture in the use of ICT and the impact of information and communication technologies on the management of agricultural holdings in risk conditions: k_1is an income, in million US dollars per one thousand hectares of land bank and k_2 is a net profit, million US dollars per one thousand hectares of land bank of the holding.

It was found that for those agricultural holdings whose activities have the required amount of statistical information, there is a correlation between the rate of change of these specific indicators with the rate of change of ICT costs over a lag of two years. For example, for agro-holding Kernel, the specific indicator k_1 which is greater than the corresponding indicator of MHP and Astarta-Kyiv (the corresponding values are 6.65; 5.56; 2.38 in 2019) correlation coefficients are equal to, respectively, 0.704; 0.596; 0.423. Regarding the indicators k_2 of the named enterprises for 2019, which have the corresponding values of 0.298; 0.582; 0.01, the correlation coefficients are slightly smaller and equal to, respectively, 0.604; 0.451; 0.326. It should be added that the study of these indicators of such a factor of their capitalization as the market value of the company (according to the analysis of quotations of their shares at international stock exchanges) as an indirect correlation factor did not confirm the appropriate level of correlation between them.

The Boxing-Jenkins method was used, the so-called time series method to forecast the total land bank of the top 5 agricultural holdings (see Figure 3) on the basis of the results of the proposed mathematical model (1)-(7).


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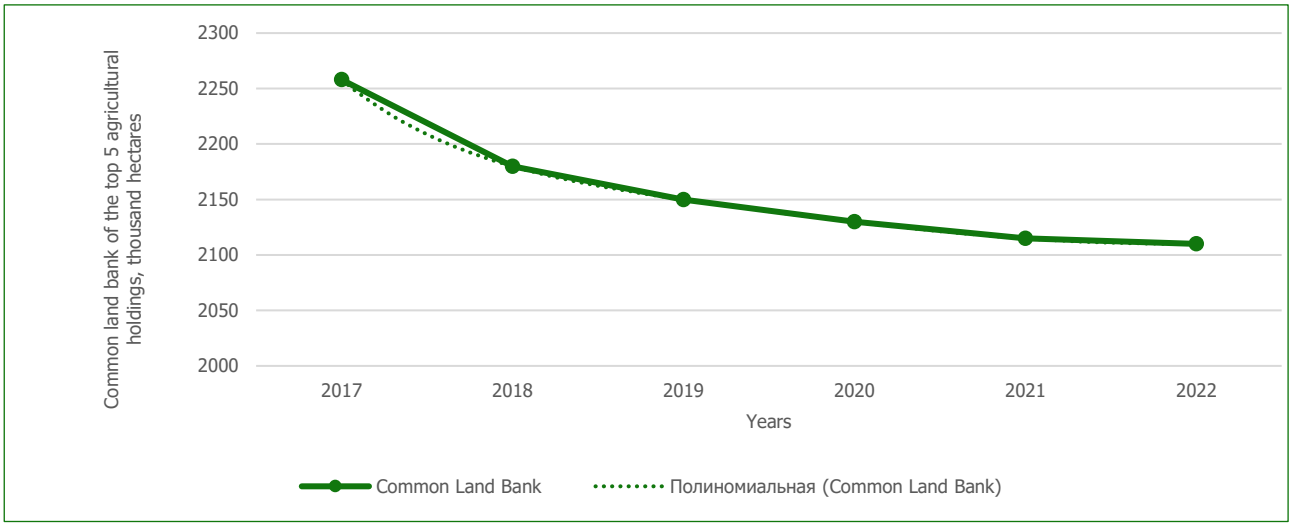


**Figure 3. Forecasting the total land bank of the top 5 agricultural holdings, thousand hectares.** *(Source: made by the author based on enterprise statistical reporting)*

A polynomial solution was formed:

$y = 1{,}375x^4 - 20{,}083x^3 + 110{,}13x^2 - 288{,}42x^1 + 2455$

where y is the value of the total land capital of the top 5 agricultural holdings, thousand hectares; x – is the corresponding time interval in years.

The statistical reliability of the model is confirmed by the following data: the average relative error of the approximation is 14.11, the Taylor test - (0,01). SSE = 69.13 MSE = 4.93. The asymmetry index is A = -0.07 and excess E = 11.4, which is less than 1,5*σ=27,96, i.e. the result is satisfactory. Pre-processing of information, analysis and consideration of non-random noise and background effects allowed to minimize the values of the Mellows criteria (0.76) and Akayke (2.65).

Analysis of equation (12) indicates that not paying attention to some stabilization of the land bank of individual agricultural holdings, the process of optimizing land resources will lead to the fact that contrary to the forecasts of some researchers and analysts, in particular, experts of the Ukrainian Agrarian Business Club total land bank will be 15-17% reduced by 2021-2022 relative to the index of 2017.

## CONCLUSIONS

According to the research, the results of which are presented in this article, the mathematical model of optimization of company management was improved and for the first-time methods of analysis were proposed, which, in particular, allow to formally determine the vector of the best ratio in areas of agricultural holdings. Using the example of MHP, it is indicated that, despite the significant level of diversification, using the proposed mathematical formalization and on the basis of published data, the ratio of major activities for 2022 should be adjusted as follows: meat processing direction - 10%; livestock - 14%; crop production - 28%; poultry - 39%; other activities - 9% to quickly minimize the impact of risks. Thus, for the first time, the example of MHP shows that even the most diversified agricultural holdings must adjust the ratio of activities permanently, in accordance with external challenges and threats. For the first time it is stated that information and communication technologies are not only a management tool but also a factor of the strategic restructuring of the company. This is confirmed, in particular, by the established correlation between the share income of agricultural holdings Kernel, MHP and Astarta-Kyiv (for 2019, correlation coefficients are 0.704; 0.596; 0.423, respectively), their specific net profit (correlation coefficients are 0.604; 0, 451; 0.326 respectively) and ICT costs.

For the first time, it has been proved that the introduction of information technologies accelerates trends in the intensive development of agricultural holdings, in particular, in the formation of land banks. Thus, for the agricultural holdings Kernel, UkrLandFarming, MHP, Agroposperis and Astarta-Kyiv, the formation of a certain stabilization of the integrated value of the land bank at the level of ~ 2.15 million hectares was revealed. The use of the mathematical model indicates that without paying attention to the own land bank policy of individual agricultural holdings, the process of optimizing the land resources of each of them will lead to the total land bank of agricultural holdings Kernel, UkrLandFarming, MHP, Agroposperis and Astarta-Kyiv will be 15-17% reduced till 2022 compared to 2017.

As a result of this study, it was first established that the introduction of new ICT stimulates the transition from extensive to intensive business methods, promotes the growth of intensive factors of modern corporate culture in management and, thus, increases the impact of intensive approaches to optimizing profitability.

Further research should focus on economic and mathematical assessment of the impact of information and communication technologies on the formation of activities of agricultural holdings in Ukraine using a representative sample of these holdings; analysis and forecast of the activity of medium-sized agricultural enterprises in terms of risk and further practical verification of the relevance of the proposed model.

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*Інграм К. Л., Дяченко О. П., Галицький О. М., Ніценко В. С., Романюк М. Д., Жумбей М. М.*

## ФОРМАЛІЗАЦІЯ ОПТИМАЛЬНОГО ВИБОРУ НАПРЯМІВ ДІЯЛЬНОСТІ АГРОХОЛДИНГІВ ЗА ВПРОВАДЖЕННЯ ІНФОРМАЦІЙНО-КОМУНІКАЦІЙНИХ ТЕХНОЛОГІЙ

**Анотація**. Розроблено методичні підходи, які дозволяють запровадити ефективне управління агрокомпанією в умовах ризику, зокрема шляхом оптимальної диверсифікації напрямів діяльності, і проаналізовано результати й напрями впливу інформаційно-комунікаційних технологій на прийняття управлінських рішень в агробізнесі. Рівень релевантності математичної моделі та методів аналізу збільшено за/проти використання аналізу періодів нерівномірності динаміки індикаторів цифрової конкурентоспроможності країни. Доведено на прикладі прогнозованого зменшення загального земельного банку провідних українських агрохолдингів, що новітні інформаційні технології стимулюють перехід від екстенсивного до інтенсивного методу ведення бізнесу, сприяють зростанню ролі інформаційно-комунікаційних технологій у збільшенні ефективності роботи підприємств. Удосконалено математичну модель управління компанією та вперше запропоновано методи аналізу, які дозволяють визначити й оптимізувати напрями діяльності агрохолдингів формалізованим чином. Як інструмент збільшення рівня релевантності математичної формалізації запропоновано вдосконалене застосування індикативного методу. Уперше вказано, що інформаційно-комунікаційні технології не тільки інструмент управління, а й фактор стратегічної перебудови компанії. Уперше доведено, що впровадження інформаційних технологій призводить до прискорення тенденцій щодо інтенсивного розвитку агрохолдингів, зокрема щодо підходів до формування земельних банків. Уперше на практичному прикладі вказано, що навіть найбільш диверсифіковані агрохолдинги мають удосконалювати співвідношення напрямів діяльності перманентно, реагуючи на зовнішні виклики. Запропонована математична формалізація може бути застосована в наукових дослідженнях і практичній роботі. Використання розробленої математичної моделі дозволило на практичному прикладі довести можливість ефективного розподілу напрямів діяльності агрохолдингів на майбутні періоди за релевантного нівелювання ризиків.

**Ключові слова:** інформаційно-комунікаційні технології, напрями діяльності, агрохолдинги, ризики, математична модель

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