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ЗМІСТ /CONTENTS

Ю. Лопатинський, М. Гуменюк, О. Шпикуляк, Д. Шеленко, Д. Неміш Організаційно-економічна адаптація малих аграрних підприємств до інституційних змін в умовах воєнного часу	10
Yu. Lopatynskyi, M. Humeniuk, O. Shpykuliak, D. Shelenko, D. Nemish Organisational and economic adaptation of small agricultural enterprises to institutional changes in wartime conditions	10
О. Захарчук, О. Вишневецька, Я. Навроцький, В. Кондратюк Інвестиційно-інноваційний розвиток насінництва України в умовах вступу в Європейський Союз	20
O. Zakharchuk, O. Vyshnevetska, Ya. Navrotskyi, V. Kondratyuk Investment and innovation development of seed production in Ukraine in the context of accession to the European Union.....	20
В. Мамчур, В. Осецький, Ю. Білявська, Г. Уманців, В. Білявський Стратегічні напрями розвитку агробізнесу в Україні	33
V. Mamchur, V. Osetskyi, Yu. Biliavska, H. Umantsiv, V. Biliavskyi Strategic vectors of agribusiness development in Ukraine	33
А. Чикуркова, Н. Покотильська, Е. Добровольська, Л. Чорнобай, О. Пацарнюк Маркетинговий моніторинг як інструмент оцінки конкурентоспроможності підприємств харчової промисловості в агропромисловому комплексі.....	47
A. Chykurkova, N. Pokotytska, E. Dobrovol'ska, L. Chornobai, O. Patsarniuk Marketing monitoring as a tool for assessing the competitiveness of food industry enterprises in the agro-industrial complex.....	47
С. Павлюк, Г. Побережець, Т. Кравченко, Н. Мірошкіна Вплив аграрного сектора економіки на сталий розвиток сільських територіальних громад	59
S. Pavliuk, H. Poberezhets, T. Kravchenko, N. Miroshkina The impact of the agricultural sector on the sustainable development of rural territorial communities	59
Н. Сіренко, О. Мельник, О. Боднар, К. Мікуляк, В. Співак Цифровізація фінансової діяльності аграрного сектору в умовах воєнного стану.....	70
N. Sirenko, O. Melnyk, O. Bodnar, K. Mikuliak, V. Spivak Digitalisation of financial activities of the agricultural sector under martial law.....	70
О. Шебаніна, С. Тищенко, О. Пархоменко, І. Хилько, В. Крайній Застосування штучного інтелекту для підвищення економічної ефективності управління землекористуванням в агропромисловому комплексі	82
O. Shebanina, S. Tyshchenko, O. Parkhomenko, I. Khylo, V. Krainii Application of artificial intelligence to improve the economic efficiency of land use management in the agricultural sector	82



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Organisational and economic adaptation of small agricultural enterprises to institutional changes in wartime conditions

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► **Abstract.** The development of small agricultural enterprises of various organisational and legal forms, strengthening their potential, and creating an effective agribusiness infrastructure becomes extremely important in the process of changing the institutional environment. In this regard, the research was aimed at substantiating the organisational and economic foundations for ensuring the adaptation of small agricultural enterprises to institutional changes, particularly those caused by wartime conditions. To achieve this goal, methods of analysis and synthesis, comparison, expert assessments, and abstract-logical methods were used. The study identifies the role of various organisational and legal forms of small agricultural enterprises in the performance of small agricultural business entities in Ukraine, based on their share in area and number of entities. An analysis of the dynamic changes in income, profitability, and efficiency of small agricultural enterprises of different organisational and legal forms was conducted. The importance

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of developing small agricultural enterprises of various organisational and legal forms to ensure the stability of agriculture is substantiated. The study of the activities of small agricultural enterprises using expert assessments provided grounds to identify problematic trends and ways to adapt to institutional changes in wartime conditions. A matrix for ensuring the organisational and economic adaptation of small agricultural enterprises to institutional changes is outlined, and the feasibility of its practical application in agricultural sector enterprises has been proven. The results of the study can be used by managers of small agricultural enterprises, government authorities, and local self-government bodies in the formation and implementation of programmes aimed at eliminating crisis phenomena in the agricultural sector

► **Keywords:** agricultural enterprise; small enterprises; adaptation; organisational and legal forms

► Introduction

Ensuring the adaptation of small agricultural enterprises of various organisational and legal forms to changes in the institutional environment, strengthening their production potential, and establishing an effective infrastructure for the agricultural sector becomes critically important in modern conditions. The issue of supporting the functioning of small agricultural enterprises remains quite complex due to the underestimation of their role in the development of rural areas, ensuring food security and employment of citizens, preserving land resources, and greening agricultural production. As a result, the activities of small agricultural enterprises of various organisational and legal forms are marked by instability and often short-term functioning. In the process of agricultural production, these entrepreneurial structures face numerous organisational, social, legal, and financial problems, which are exacerbated by crisis phenomena, particularly those caused by martial law in Ukraine.

With regard to the agrarian sector of the national economy, the basis of its institutional transformation relates to the formation of the potential to meet the modern challenges of food security, as substantiated in the works by A. Hutorov *et al.* (2021) and O. Artyukhin *et al.* (2023). Yu. Hubeni (2019) and Y. Maksymiv *et al.* (2022) examined the prospects for the development of organisational and legal forms of agricultural entrepreneurship, taking into account the awareness and readiness for entrepreneurship among the population under institutional changes. M. Malik (2023) researched the theoretical-methodological and organisational-economic foundations of institutional and economic policy for the development of agricultural entrepreneurship in Ukraine. I. Yatsiv & H. Cherevko (2022) identified the patterns of the impact of the size of agricultural enterprises on their operational efficiency. V. Zhuk *et al.* (2023) investigated the mechanisms for compensating damages caused by military actions to agricultural enterprises. I. Balaniuk & B. Ivanochko (2023) conducted scientific research on the issues of institutional dynamics of small agricultural enterprises' development in connection with the functioning of local communities. T. Yavorska *et al.* (2019) explored the theoretical-methodological foundations for the development of family farms in rural areas. K. Kolarov *et al.* (2021) studied the determinants related to the process of internationalisation of small and large enterprises, identifying the differences in this process. I. Bezhenar & O. Hryshchenko (2023) identified key problems affecting the activities of farms, as well as determined priority directions, potential, and development opportunities in the context of global challenges and martial law.

Experience and practice in developed countries convincingly confirm that small agricultural enterprises of various organisational and legal forms are, and will continue to be, an organic component of modern agricultural production. Aiming at the production of environmentally friendly products, engaging in craft production of unique agro-food products, ensuring a high degree of flexibility and diversification of activities, small agricultural enterprises of various organisational and legal forms could become the foundation of the Ukrainian agricultural sector and occupy a significant niche in the domestic and foreign markets. The purpose of the study was to outline the main performance indicators of small agricultural enterprises of various organisational and legal forms of management, problems, and prospects of their development in Ukraine under conditions of institutional changes.

► Materials and methods

To achieve the goal, the data of the State Statistics Service of Ukraine were used (Official website of the State Statistics Service of Ukraine, n.d.). The object of statistical observation and indicative assessment are small agricultural enterprises of various organisational and legal forms, including small farms, which collectively determine the main array of parameters and indicators. The analysis process covers the activities of small agricultural enterprises in the pre-war period of 2016–2021 and the period of martial law in 2022–2023. The level of development of small agrarian entrepreneurship for 2016 was assessed on the basis of the form “Report on costs for the production of agricultural products (works, services), 2-farm (annual)”, and for 2017–2023 on the basis of the form “Report on costs for production of products (works, services) of agriculture, 2-farm (annual)” (Order of the State Statistics Service of Ukraine No. 153..., 2022). This form is submitted by farms and small enterprises engaged in agricultural activities to the body of the state statistics service of the relevant territory according to the list determined by the relevant body. The identification of the reporting subjects and the information filling of the statistical sample is carried out according to “The methodology for conducting a sample survey of farms, small enterprises in agriculture” (Order of the State Statistics Service of Ukraine No. 421..., 2022). According to this methodology, the main indicators of economic activity of enterprises in the field of agriculture are recorded statistically. This observation is selective in the degree to which units are covered, not continuous. In the process of research, using the calculation and analytical method, the following indicators of the economic activity of small

agricultural enterprises were evaluated: net income from the sale of agricultural products in general and in the section of the branches of plant and animal husbandry, net profit from the sale of agricultural products in general and in the section of the branches of crop and animal husbandry, the profitability of agricultural products in general and in the cross-section of the fields of crop production and livestock production. The use of the grouping method made it possible to assess the structure of the area of agricultural land of various organisational and legal forms of small agricultural enterprises and to compare the level of their economic efficiency.

The abstract-logical method, which is used to identify logical relationships between the elements of the studied system, made it possible to investigate the causes of the crisis in the management of small agricultural enterprises in Ukraine, to clarify the role and significance of martial law in its occurrence. The application of the method of expert evaluations made it possible to more accurately assess the problems of functioning of small agricultural enterprises of various organisational and legal forms and ways of their adaptation from a professional point of view. During the research, the comparison method was also applied in order to compare over time the indicators of small agricultural enterprises of Ukraine of different organisational and legal forms of management.

► Results

Agriculture is the dominant sector of the national economy of Ukraine, which forms the country's export potential, guarantees food security, and demonstrates a sufficient level of development efficiency in the difficult conditions of martial law. At the same time, a significant share in the production of agricultural products is occupied by small enterprises.

The formation of an effective structure of the agricultural sector is impossible without the development of small agrarian businesses. Small agrarian entrepreneurship is a necessary element of the dynamic development of rural areas, characterised by high flexibility and the ability to adapt to changes in economic conditions,

contributing to providing the population with an appropriate level of income and other benefits. However, the existing organisational and economic mechanism of the development of small agricultural enterprises in the conditions of institutional changes is more problematic than in large farms, which is emphasised in this study.

The importance of small agricultural enterprises in the conditions of institutional changes is manifested through such functions as: innovative, stimulating, financial, and social (Lopatynskyi *et al.*, 2024). The innovative function is manifested in the innovative approach of entrepreneurs to the organisation of agricultural production. Stimulating the development of rural areas through the development of infrastructure and increasing the level of employment is the basis of the stimulating function of small agrarian entrepreneurship. The financial function is conditioned by the fact that small agrarian entrepreneurship is a significant source of filling local budgets. At the same time, small agrarian entrepreneurship is a socially responsible business (Yatsiv *et al.*, 2024), which is the essence of the social function, realised in particular through the development of social farming. The studied form of agrarian entrepreneurship is currently at the initial stage of development in Ukraine. However, in the conditions of post-war recovery, its development will be an objective requirement of the time.

The analysis of the structure of the organisational forms of the formed sample of small agrarian enterprises proved that the most common form of organisation of small agrarian enterprises in Ukraine today are farms (Fig. 1). According to statistical data, the share of farms in the number of subjects of small agrarian entrepreneurship is 92.0% (Official website of the State Statistics Service of Ukraine, n.d.). The predominance of the share of farms among other organisational and legal forms in Ukraine is justified by the fact that in the process of reorganisation of collective agricultural enterprises, family members were more often united to implement joint activity, as they could not independently ensure effective agricultural production.

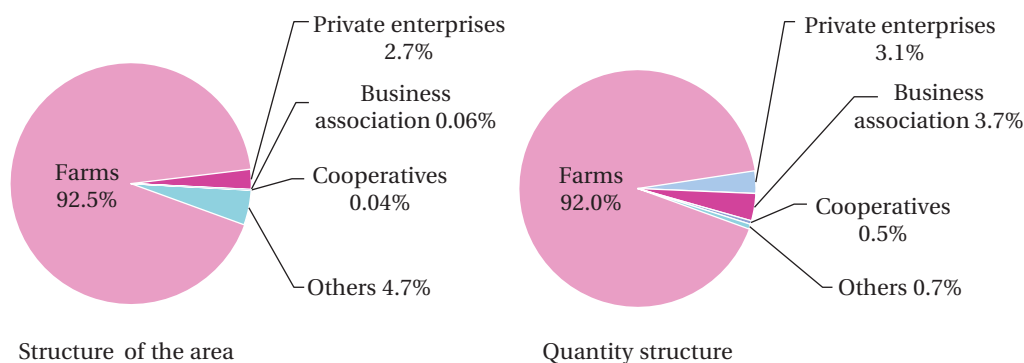


Figure 1. The share of forms of management of small agricultural enterprises in their total area and number in Ukraine in 2021

Source: compiled by the authors based on the statistical observation data from the Official website of the State Statistics Service of Ukraine (n.d.)

The study of the distribution of general land use in the section of the formed sample of small agricultural formations allowed for the characterisation of the level of

prevalence of subjects of various forms of management in specific conditions. Farms cultivating 92.5% of the area of agricultural land occupy 92.0% in the structure of the

number of small agricultural enterprises of different organisational and legal forms. That is, the relationship is proportional. This proves the predominant concentration of land resources in this organisational form of management and the focus on the production of products that require a sufficient level of land supply. At the same time, business associations cultivating 0.06% of the area occupy 3.7% of the total number of small subjects of the agrarian sphere. Cooperatives cultivating 0.04% of the area make up 0.5% of the total number of small agricultural formations. Private enterprises cultivate 2.7% of the area and occupy 3.1% of the total number, and other forms of small agrarian enterprises cultivate 4.7% of the area and occupy only 0.7% of the total number of subjects of small agrarian entrepreneurship.

The specified share of farms in the total number of small agricultural enterprises and the corresponding land use area in general show that at this stage of reforming agrarian relations, such farms managed to occupy the main place among small commodity producers. This trend is well-founded because small farms are the most

common form of management in most countries of the world with highly developed economies, proving their right to exist and demonstrating high efficiency.

According to the data in Table 1, there is an increase in the dynamics of the volume of net revenue from the sale of agricultural products by small enterprises of all forms of management. During the analysed period, the volume of net revenue from the sale of agricultural products of small enterprises increased by 160.4%, in particular, small farms by 111.5%. The amount of net revenue from the sale of plant products by small enterprises in 2023 compared to 2016 increased by 176.1% and from the sale of livestock products decreased by 16.9%. In particular, the following change in this indicator was observed in small farms: growth by 115.4% in crop production and by 6.1% in livestock production. The main reason for the increase in revenue in the field of crop production is the price factor. The reason for the decrease in the income of small agricultural formations in the field of animal husbandry was the refusal of this type of activity due to unprofitability.

Table 1. Net revenue from the sale of products by small agricultural enterprises of various organisational and legal forms in Ukraine, UAH million

Indicator	2016	2017	2018	2019	2020	2021	2022	2023	Deviation (%) of 2023 compared to 2016 2022	
Net income (revenue) from the sale of agricultural products										
All organisational and legal forms of small agricultural enterprises	38,737	38,973	50,160	63,844	85,784	134,168	81,505	100,861	160.4	23.7
Small farms	29,649	34,823	38,350	46,298	50,877	85,562	50,950	62,696	111.5	23.1
The specific gravity of small farms, %	76.5	89.4	76.5	72.5	59.3	63.8	62,5	62.2	-14.3	-0.3
Net income (revenue) from the sale of plant products										
All organisational and legal forms of small agricultural enterprises	35,578	37,252	47,445	60,146	83,033	131,728	79,044	98,237	176.1	24.3
Small farms	28,591	33,402	37,505	45,527	50,056	84,642	50,225	61,573	115.4	22.6
The specific gravity of small farms, %	80.4	89.7	79.0	75.7	60.3	64.3	63.5	62.7	-17.7	-0.8
Net income (revenue) from the sale of livestock products										
All organisational and legal forms of small agricultural enterprises	3,159	1,721	2,715	3,698	2,750	2,440	2,461	2,624	-16.9	6.6
Small farms	1,058	1,421	845	771	820	919	725	1,123	6.1	54.9
The specific gravity of small farms, %	33.5	82.6	31.1	20.8	29.8	37.7	29.5	42.8	9.3	13.3

Source: calculated by the authors based on statistical observation data from the Official website of the State Statistics Service of Ukraine (n.d.)

Under conditions of martial law, small agricultural enterprises faced the problems of blocking ports, increasing the cost of logistics, and direct losses caused by the war (such as demining of fields, damage to agricultural machinery, occupation of territories, and illegal export of Ukrainian grain). A significant problem for them is the limited possibilities of obtaining bank loans. The situation with insufficient access to bank loans and the general increase in the cost of capital made it difficult to replenish financial resources and carry out activities.

In connection with the establishment of new sales channels and the restoration of the opportunity to export products in 2023, the amount of agricultural products sold by small enterprises increased dynamically compared to 2022, but did not reach the pre-war period. Thus, the net income from the sale of agricultural products in general increased by 23.7%, in particular, small farms by 23.1%. Net income (revenue) from the sale of plant products increased by 24.3%, in particular, small farms by 22.6%. At the same time, net income (revenue) from the

sale of livestock products increased by 6.6% in all organisational and legal forms of small enterprises and by 54.9% in small farms. On the contrary, in 2022, a decrease in this indicator was observed compared to the pre-war period, since small farms were among the enterprises that lost livestock as a result of hostilities. The set of support programmes for these farms contributed to the increase in sales volumes in 2023.

The specific weight of small farms in the amount of revenue from the sale of agricultural products in general from 2016 to 2023 decreased from 76.5 to 62.2%, in particular from the sale of plant products from 80.4 to 62.7%. At the same time, sales of livestock products increased

from 33.5 to 42.8%, respectively. It should be noted that the decrease in the specified indicator in the period until 2022 was quite dynamic. Thus, the share of small farms in ensuring the volume of livestock production was smaller and amounted to 29.5%. The small volume of revenue from the sale of livestock products is explained by the high labour intensity and high cost of its production. This leads to the fact that livestock products make up a small share of the gross volume of products produced by small agricultural enterprises. It is appropriate to emphasise the dynamic increase in the amount of profit from the sale of agricultural products by small agricultural enterprises in the pre-war period (Table 2).

Table 2. Profit from the sale of products by small agricultural enterprises of various organisational and legal forms in Ukraine, UAH million

Indicator	2016	2017	2018	2019	2020	2021	2022	2023	Deviation (%) of 2023 to	
									2016	2022
Profit, loss (-) from the sale of agricultural products										
All organisational and legal forms of small agricultural enterprises	11,486	10,636	12,179	13,859	23,795	49,614	23,674	21,028	83.1	-11.2
Small farms	8,826	9,582	9,302	10,170	13,737	31,066	13,891	13,086	48.3	-5.8
The specific gravity of small farms, %	76.8	90.1	76.4	73.4	57.7	62.6	58.7	62.2	-14.6	3.5
Profit, loss (-) from the sale of plant products										
All organisational and legal forms of small agricultural enterprises	11,043	10,548	11,872	13,425	23,507	49,372	23,461	20,686	87.3	-11.8
Small farms	8,736	9,518	9,195	10,098	13,608	30,943	13,808	12,919	47.9	-6.4
The specific gravity of small farms, %	79.1	90.2	77.5	75.2	57.9	62.7	58.9	62.5	-16.6	3.6
Profit, loss (-) from the sale of livestock products										
All organisational and legal forms of small agricultural enterprises	443	88	306	436	287	243	214	341	-23.0	59.4
Small farms	90	65	106	73	129	123	83	167	85.0	100.6
The specific gravity of small farms, %	20.3	73.9	34.6	16.7	44.9	50.6	38.8	48.8	28.5	10.0

Source: calculated by the authors based on statistical observation data from the Official website of the State Statistics Service of Ukraine (n.d.)

In 2023, compared to 2016, the amount of profit from the sale of agricultural products by small agricultural enterprises of various organisational and legal types increased by 83.1%, in particular, small farms by 48.3%. The profit from the sale of plant products of small agricultural enterprises increased by 87.3%, in particular, small farms by 47.9%. Profit from the sale of livestock products decreased by 23%, while that of small farms increased by 85%. Compared to 2022, in 2023 it is worth noting a decrease in the amount of profit received from the sale of agricultural products by small agricultural enterprises in general by 11.2%, in particular, by 11.8% of crop enterprises, and an increase in the field of animal husbandry by 59.4%. If similar trends were observed in small crop farms, then a more dynamic increase in profit was characteristic of these livestock farms.

The specific gravity of small farms in the amount of profit from the sale of agricultural products by small agrarian enterprises decreased from 76.8 to 62.2%, from the sale

of plant products – from 79.1 to 62.5%. On the contrary, the specific weight of small farms in the amount of profit from the sale of livestock products increased from 20.3 to 48.8%, respectively. Despite the insignificant amount of profit received from the sale of livestock products by small farms, its share in the all-Ukrainian volume of this type of profit is quite significant. An increase in the volume of sales of livestock products by small agricultural enterprises to a level necessary to meet the needs of the population, increase the efficiency of the industry, and create an appropriate export potential to ensure competitiveness in the world market is one of the main prerequisites for the development of these farms at the current stage.

At the same time, it should be noted that the majority of income (97.4%) and, accordingly, profit (98.4%) from the sale of agricultural products by small agricultural enterprises of all organisational and legal forms is provided by the sale of plant products. This is due to the desire of small agricultural enterprises to quickly return the

invested funds thanks to the sale of products with higher profitability. Similar trends are present in relation to small farms, which provide 98.2% of net income and 98.7% of net profit at the expense of the crop industry.

The amount of net income (revenue) from the sale of agricultural products of small agricultural enterprises of all organisational and legal forms grew at a faster rate

compared to the growth of the absolute amount of profit from sales. This characterises the insufficient level of production efficiency of such enterprises and makes it necessary to increase it. The dynamics of the profitability of agricultural production in general and in the cross-section of crop and livestock industries in small agrarian enterprises of various forms of management is presented in Table 3.

Table 3. The level of profitability of agricultural products produced by small agricultural enterprises of various organisational and legal forms in Ukraine, %

Indicator	2016	2017	2018	2019	2020	2021	2022	2023	Deviation of 2023 from	
									2016	2022
All organisational and legal forms of small agricultural enterprises										
Profitability of agricultural products	41.4	34.0	32.2	26.6	40.5	58.7	40.9	26.3	-15.1	-14.6
plant products	49.3	36.5	36.9	29.5	42.9	59.9	42.2	26.7	-22.6	-15.5
livestock products	20.2	8.5	12.0	14.1	8.9	11.1	9.5	14.9	-5.3	5.4
Small farms										
Profitability of agricultural products	42.4	38.0	32.0	28.2	37.0	57.0	37.5	26.4	-16.0	-11.1
plant products	44.0	39.8	32.5	28.5	37.3	57.6	37.9	26.6	-17.4	-11.3
livestock products	9.3	4.8	14.4	10.4	18.7	15.4	12.9	17.4	8.1	4.5

Source: calculated by the authors based on statistical observation data from the Official website of the State Statistics Service of Ukraine (n.d.)

The profitability of agricultural products in small agricultural enterprises of all forms of management was unstable. In the pre-war period, it increased from 41.4% in 2016 to 58.7% in 2021, but decreased to 26.3% in 2023. The level of profitability of crop production is characterised by a gradual increase until 2021 to the level of 59.9% and a decrease in 2023 to the level of 26.7%. The profitability of livestock production decreased by 5.3 percentage points. The profitability of agricultural products of small farms was also unstable. A more dynamic decrease was characteristic for the field of crop production, since in the conditions of martial law, these agricultural producers had problems with the sale of grain and industrial crops. As a result, not all farms from this category were able to ensure the profitability of their activities, so some of them were forced to stop working. Small livestock farms, on the contrary, showed an increase in the level of profitability until 2021 and no significant decrease in 2022, despite the fact that livestock farms in the eastern regions were destroyed.

The development of small agrarian business is an urgent problem for the creation of an institutionally effective model of the national economy of Ukraine and the socio-economic development of rural areas, as these challenges are exacerbated by wartime conditions and the growing integration of Ukraine into the structures and markets of the European Union, which requires taking into account the principles of conducting business in accordance with the requirements of the Common Agricultural Policy of the EU and the norms of the European Green Deal (Shpykuliak *et al.*, 2024).

Difficult wartime conditions force small agricultural enterprises of various organisational and legal forms to seek ways to adapt to the changed institutional environment. The adaptability of small agricultural enterprises is determined by their high manoeuvrability, the ability to quickly adjust to changes in the external environment due to the flexibility of internal subsystems, the capacity to self-organise, and the generation of innovative ideas in the agricultural sphere, which involves the formation of a certain organisational and economic toolkit. Based on expert generalisations of factors that determine the ease of adaptation, trends, and methods of adaptability, a matrix for ensuring the organisational and economic adaptation of small agricultural enterprises to institutional changes was constructed, which is presented in Figure 2.

According to M. Malik (2023), the general problems of the development of entrepreneurship in the countryside remain: limited opportunities to attract financial resources, use of outdated equipment and insufficient implementation of advanced technologies, limited motivation for innovation, low competitiveness in the sphere of labour remuneration, ineffectiveness of state regulatory mechanisms, insufficient support from authorities and local self-government, as well as legal instability and deficiencies in regulatory mechanisms. Besides, this list should be supplemented with such problems as: lack of support for novice farmers and young farmers, limited provision of advisory services to small agrarian enterprises, and low interest in cooperation among subjects of small agrarian entrepreneurship.

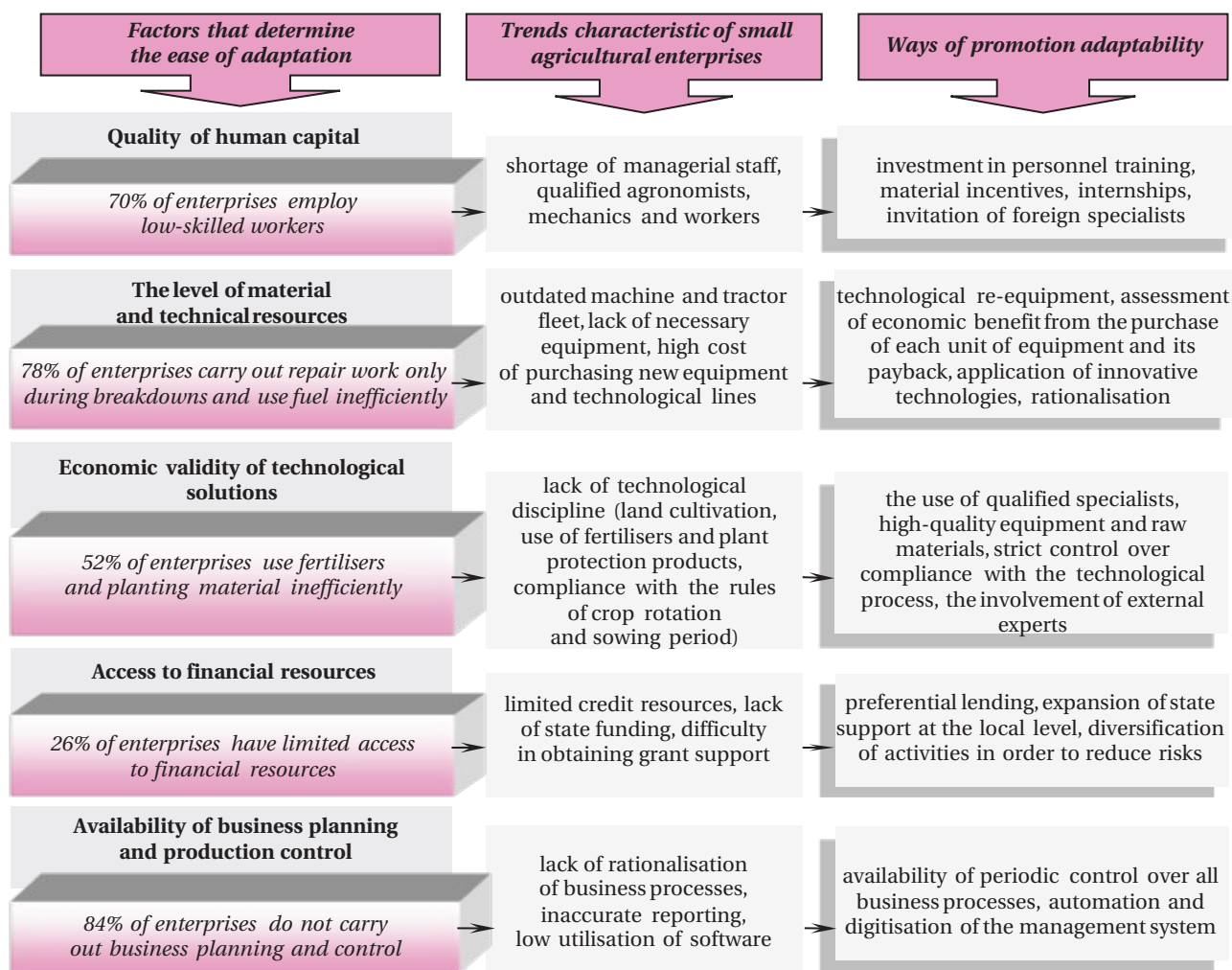


Figure 2. Matrix for ensuring organisational and economic adaptation of small agricultural enterprises to institutional changes

Source: formed by the authors based on their own research

The sustainable development of small agrarian enterprises depends on the implementation of effective investment projects, and successful adaptation, respectively, on the ability of enterprises to implement innovations. However, the existing level of financial support for most of these farms does not allow for the application of innovative potential in the production process to ensure better quality and higher efficiency. The substantiation of ways to solve the problems of the development of small agrarian enterprises and the achievement of long-term efficiency on an innovative and investment basis is due to the need for their rapid adaptation to changes in economic conditions.

► Discussion

In scientific works, it can be found the statement that the level of economic efficiency mostly depends not on the organisational and legal form of a small agricultural enterprise, but on the level of provision of each specific enterprise with means of production – basic means of production and land resources (Havrylchenko, 2021). In small businesses, the motivation of their managers is also

important, since during their professional activities they realise only about 30-40% of their potential, and motivation is a decisive factor in business efficiency, the creation of favourable working conditions and the use of incentives (Boryshkevych & Yakubiv, 2023). R. Dhillon & Q. Moncur (2023) note that small farms play an important role in ensuring global food security. In addition, smallholder agriculture provides environmental, cultural, social and economic benefits through increased crop diversification, self-sufficiency and employment. Accordingly, the future belongs to those farms in which, on the one hand, the interests of owners and employees will be interconnected (due to proper remuneration), and on the other hand, organisational and economic relations will be highly developed. The realisation of the ancient dream of rural residents that the land and means of production should belong to those who work for them gives a significant effect in small business. If the subject of entrepreneurial activity is one person or family, the owner and worker are combined in one person, then the level of business interest is created, which ensures the competitiveness and development of small business.

It is appropriate to emphasise that small agrarian enterprises of various organisational and legal forms of management are a considerable resource for the development of agriculture in Ukraine; they direct their activities to saturate the market with consumer products and reduce the level of unemployment in rural areas. Small agrarian enterprises, being market-type entities, under the conditions of the presence of appropriate “rules of the game”, are able to ensure the production of high-quality competitive products and high profitability (Bose *et al.*, 2017). The results of the study by C. Dias *et al.* (2021) confirm that by achieving a high level of environmental performance, farms can achieve a competitive advantage by mitigating their profound environmental impact. However, the modern institutional environment of small agrarian entrepreneurship in Ukraine does not provide favourable conditions for its functioning. In the process of reforming the national agricultural sector, small agricultural enterprises of various organisational and legal forms did not become the core in the organisational structure of agricultural production in our country, which would generate the basis of the agricultural sector.

The lack of appropriate stimulating factors for economic activity in the agricultural sector hinders the processes of development and effective functioning of small agrarian enterprises of various organisational and legal forms of management. One of the prospects for the development of small agricultural enterprises is the search for new customers and sales markets, since the supply chains that were previously formed are currently partially destroyed (Bezhenar & Hryshchenko, 2023). However, the majority of small agricultural enterprises of various organisational and legal forms are focused on domestic markets and do not use international markets for their growth and competitiveness (Protosvitska *et al.*, 2021). As proven by O. Levandivskyi & V. Humeniuk (2022), low prices for agricultural products and high prices for industrial goods negatively affected and still affect the purchasing power of peasant households. Despite the fact that globalisation and world integration processes are shifting the emphasis in competition towards the growing role of small agricultural enterprises, the majority of domestic farms are not ready to actively compete in highly competitive world markets. First of all, difficulties arise in connection with the existing standardisation system, which requires additional funds to confirm the conformity of manufactured products, standardisation and certification, and the introduction of quality management, etc.

Enterprises that will use new technologies will be competitive both in the foreign and domestic markets (Humeniuk *et al.*, 2022). An increase in the production of agricultural crops contributes to the growth of the export potential of agriculture (Aleskerova & Fedoryshyna, 2023). The creation and development of new agricultural enterprises should be carried out immediately according to European standards, taking into account

environmental friendliness, safety and energy efficiency of activities, which is due to the innovative component of their development.

► Conclusions

The growing role of small agrarian entrepreneurship during the crisis associated with martial law is well-founded. The reduction of production in the sector of large farms at a significant pace, alongside the flow of production resources from this sector to small farms during the crisis period, was due not so much to a drop in the level of productivity, but to the low manoeuvrability of large producers in all aspects of their activities. On the other hand, small agricultural enterprises of various organisational and legal forms became “victims” of material losses, loss of product sales channels, and an increase in the cost of logistics services, which led to a decrease in production volumes and profitability.

The adaptation of small agrarian enterprises of various organisational and legal forms of management to dynamic changes in the institutional environment will provide an opportunity to solve problems related to the country's food security and strengthen its position in the European market. It is worth noting that small agricultural enterprises perform extremely important social functions to a greater extent, such as creating jobs and reducing the unemployment rate, ensuring the flexibility and stability of the economy, developing human capital, providing sources of income for the population, forming the middle class of society, and reducing public spending on social protection and social security of vulnerable population groups.

That is why small agricultural enterprises are becoming more widespread each year. Quite often, such enterprises are profitable, produce unique products, and use personal contacts or international grants to enter foreign markets. Therefore, commercial banks are willing to work with them, and investors are ready to invest their own capital with greater interest than in medium and large agricultural enterprises, which generally contributes to the development and organisational and economic adaptation of small agricultural enterprises to institutional changes.

It should be noted that in the course of the conducted research, the activity of small agricultural enterprises was evaluated through the economic aspect. However, given the goals and functions they perform, the efficiency of this form of management is a combination of social, economic, technological, and environmental efficiency, the assessment of which will form the basis for further research.

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► Conflict of interest

None.

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Організаційно-економічна адаптація малих аграрних підприємств до інституційних змін в умовах воєнного часу

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► **Анотація.** Розвиток малих аграрних підприємств різних організаційно-правових форм, зміцнення їхнього потенціалу та створення ефективної інфраструктури агробізнесу стає надзвичайно важливим у процесі зміни інституційного середовища. У зв'язку із цим, дослідження було спрямоване на обґрунтування організаційно-економічних засад забезпечення адаптації малих аграрних підприємств до інституційних змін, які обумовлені, зокрема й умовами воєнного часу. Для досягнення цієї мети використано методи аналізу та синтезу, порівняння, експертних оцінок, абстрактно-логічний. У дослідженні визначено місце різних організаційно-правових форм малих аграрних підприємств у результативності діяльності суб'єктів малого аграрного підприємництва в Україні за часткою у площі та кількості суб'єктів. Здійснено аналіз динамічних змін дохідності, прибутковості та рентабельності малих аграрних підприємств різних форм здійснення господарської діяльності. Обґрунтовано важливість розвитку малих аграрних підприємств різних форм здійснення господарської діяльності для забезпечення стабільності сільського господарства. Дослідження діяльності малих аграрних підприємств методом експертних оцінок дало підстави визначити проблемні тенденції та шляхи адаптації до інституційних змін в умовах воєнного часу. Окреслено матрицю забезпечення організаційно-економічної адаптації малих аграрних підприємств до інституційних змін, доведено доцільність її практичного застосування на підприємствах аграрного сектора. Результати дослідження можуть бути використані керівниками малих аграрних підприємств, органами державної влади та місцевого самоврядування при формуванні та реалізації програм щодо усунення кризових явищ в аграрній галузі

► **Ключові слова:** аграрне підприємство; малі підприємства; адаптація; організаційно-правові форми



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Investment and innovation development of seed production in Ukraine in the context of accession to the European Union

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► **Abstract.** The study aimed to assess the investment and innovation support of seed production, to develop measures to improve efficiency and to propose proposals for protecting the rights of breeders to receive royalty and breeding payments. Monographic, economic statistical, tabular and graphical, empirical, comparative analysis, forecasting, and abstract and logical methods were used in the study. The study analysed the organisation and functioning of the seed industry in Ukraine. The main indicators of the development of seed production of cereals, legumes and oilseeds were investigated, and the outstripping rates of development of imports over exports and, accordingly, Ukraine's import overdependence, which leads to vulnerability in the global seed market, were revealed. The dynamics of costs to produce seeds of cereals, oilseeds and legumes is summarised, and the standard cost of wheat seeds is calculated. Proposals were developed to protect the rights of breeders in terms of protecting intellectual property rights to plant varieties, accounting for the best practices of European countries. The actual and proposed value-added chains to produce conditioned seeds in Ukraine were built. The most important indicators of seed production growth in Ukraine are the volume of sowing (2,300-2,500 thousand tonnes), exports (77 million USD), and imports (350 million USD). The largest share in the cost structure of all producers is the production of seeds, which are then delivered to the company for processing (40-80%, depending on the category of producers). The amount of royalties paid annually averages 90 million UAH, with a potential of 900 million UAH. Breeding payments are not paid in Ukraine at all, although they could amount to 725.7 million UAH

► **Keywords:** conditioned seeds; cost; commercialisation; breeding institutions; added value; optimisation

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► Introduction

The development of agricultural production is based on modern breeding, variety renewal and timely variety replacement, and an effective national seed system that ensures optimal use of the genetic potential of Ukrainian varieties and meets the needs of agricultural producers for conditioned seeds. This will increase crop yields, reduce costs and increase the economic efficiency of agricultural production, as well as strengthen the competitive position of the Ukrainian seed industry and the agricultural sector in general.

The genesis of breeding and seed production in Ukraine, strengthening the position of Ukrainian seed producers in the international market, foreign investment (Sergeyeva *et al.*, 2020) to build a world-class seed infrastructure (Borras *et al.*, 2020; Qian, 2021) are not possible in the future without the implementation of European standards, without Ukraine's membership in the International Organisation for Economic Cooperation and Development (OECD) and accession to variety certification schemes. The use of conditioned seeds in agriculture is a key factor in its genesis and the basis for increasing the economic efficiency of the crop production industry. This is evidenced by global trends related to food security, bio- and genetic engineering, conversion to biofuels, adaptation to meteorological changes, etc. The constant demand in the global food market requires increasing agricultural potential, including through seed production. The role of innovative factors in agriculture and the economy has increased and will continue to grow in the future (Bass *et al.*, 2020). This can be achieved through a well-organised and efficiently operating Ukrainian seed industry.

The development of the seed industry and related problems of providing agriculture with highly productive seeds and planting material, the issues of increasing the efficiency of seed production and forming strategic directions for its development have been discussed and clarified in the research of many Ukrainian and foreign scientists. The development of Ukrainian agriculture is largely dependent on the supply of high-quality seeds for high yields. All other production factors also depend on the quality of seed material. For instance, J. Singh *et al.* (2019) estimated that the contribution of quality seeds alone to total crop-dependent production is estimated to be 15–20% and that this figure can be increased to 45% if other inputs are managed effectively.

K. Deconinck (2019) and P. Singh (2021) argue for the need to build a seed production system that will be the basis for food security. A seed system includes technological, organisational, market and non-market institutions that provide access to quality seed. D. Nabuuma *et al.* (2022) analysed the importance of seed system interventions in the food supply of low- and middle-income countries. The researchers recognise that food producers and consumers are often uninformed about the availability of seeds and other agricultural inputs. Therefore, the extent to which seeds, and seed systems directly or indirectly contribute to improved nutrition has not been proven or determined.

To meet the needs of agricultural producers with updated crop varieties, the seed system should take measures including plant breeding and variety development programmes to provide agricultural producers with

quality seeds. S. Gairhe *et al.* (2021), in an analysis of the cultivation and marketing of maize seeds, concluded that it is necessary to provide state support to farmers in the innovation of their technologies for commercial seed production. The limited availability of investment resources for small farmers and other value chain actors is a major constraint in the seed industry.

D.A. Vermunt *et al.* (2022) study the place of seed systems in the provision of seeds. This group of scientists considers seed systems to be market and non-market institutions for providing farmers with conditioned seeds, technologies, organisational structures, etc. The seed system is regulated through plant breeding and propagation methodologies, official regulation, certification, and laws and regulations. Due to the high price, small agricultural producers usually do not use high-quality conditioned seeds. On the contrary, large and medium-sized enterprises are users of conditioned seeds as natural capital (Mattana *et al.*, 2022).

The importance of seed production in the development of agricultural science was also studied by Ukrainian scientists O. Zakharchuk *et al.* (2019). The study included a retrospective analysis of the formation of seed production in Ukraine and an analysis of the current state and prospective ways of its development; organisation of market infrastructure and determination of the patterns of its effective functioning; highlighting problems and developing measures to improve the commercial circulation of seed material based on foreign experience, as well as the introduction of fees for the use of seeds as an object of intellectual property.

The current development of the seed industry is hampered by the following problems: the prevalence of foreign varieties in the seed market, the low level of state support for seed production and its further reduction, the lack of certified seeds from agricultural producers, etc. Their solution will have a positive impact on the level of supply of seeds of Ukrainian varieties to agricultural enterprises, the development of the export potential of the seed industry, primarily oilseeds and grains, and the inflow of investments that will ensure high and stable development of Ukrainian seed breeding and seed production. All these problems require a comprehensive study and analysis and the development of effective ways to solve them. The study aimed to comprehensively analyse the level of investment and innovation support for seed production, to develop ways to improve the efficiency of the industry and to make practical proposals aimed at protecting the intellectual rights of breeders and variety owners concerning royalties and breeding payments.

► Materials and methods

The main methods used in the study of the production cost of Ukrainian-conditioned seeds were the dialectical method and the systematic approach. Monographic (to present the opinions of scientists on the issue, to study the current state of seed production of cereals, legumes and oilseeds); economic and statistical (Yang, 2022) (to analyse the structure of costs to produce crop production), tabular and graphical (to visualise the results of the study) were also used. At the same time, empirical

(McEwan, 2010) (to consider the experience of other countries in protecting intellectual property rights to plant varieties, collecting royalties and breeding payments and implementing their experience in their practice); comparative analysis (to identify the most significant problems of Ukrainian seed production); analytical forecasting method (Masayuki, 2022) (to determine the potential amount of royalties and breeding payments from the use of certified seeds by Ukrainian farmers); abstract and logical (to summarise the results of the study and formulate conclusions).

Seed production is a logical extension of breeding. The use of breeding techniques is necessary in some seed production technologies, for example, for cereals. Therefore, varietal resources were assessed and analysed. The improvement in the qualitative and quantitative composition of plant varieties of Ukrainian breeding, which are recognised as suitable for cultivation, has been recognised by experts of the World Intellectual Property Organisation. Indicators calculated according to the Ukrainian Institute of Plant Variety Expertise (n.d.) indicate the quality of national varietal resources.

The production of varietal seeds is the basis for the development of the agricultural sector. The study firstly analysed the structure of the cost of seed production, which includes seeds for sowing for further reproduction, seed insurance fund, wages, salaries, payroll, fuel, fertilisers, plant protection products, routine maintenance, depreciation, and seed processing costs. Production costs and value-added cannot be considered separately. These two values are interrelated and determine the selling price of conditioned seeds. To assess the intensity of changes in production losses over time, time series indicators were used.

The analysis of the seed production of conditioned seeds, in addition to studying the structure of production costs and added value, is complemented by the study of such indicators as the sown area, production volumes of certified seeds of the most common crops of Ukrainian and foreign selection, calculation of potential royalty and breeding payments. The system of indicators is built based on an attribute assessment using descriptive statistics and statistical analysis methods. The study analysed the production of additional basic and certified seeds by different categories of producers and built a scheme to produce seeds of different categories by the institutions of the National Academy of Agrarian Sciences of Ukraine (NAAS) network.

The mechanism for managing the market for conditioned seeds involves the development and implementation of mandatory breeding payments and royalties. Given the lack of experience in protecting intellectual property rights, the experience of other countries was used and adapted to Ukrainian realities. Based on this, the potential number of payments that can be further directed to the development of breeding science was calculated.

To deepen the study, the research analysed the conditions of seed production and bringing it to consumer conditions by different categories of processors in Ukraine and the world, from its sale after harvesting the seed material to its sale on the market. For this purpose, the chain analysis method was used (Depro & Rouse, 2022). The analysis used data from Euroseeds (n.d.), the National Academy of Agrarian Sciences of Ukraine (n.d.) and

private producers and provided a new vision of the formation of the final standard price of conditioned seeds, incorporating the costs of all links in the value chain and the profit received.

Therefore, the stages of the study are: generalisation of research on seed production, assessment of seed production in the dynamics of national and foreign enterprises, determination of the share of seeds of Ukrainian selection in the total volume, calculation of their cost and recommendations for improving the state of Ukrainian seed production by spreading the practice of introducing royalty and selection payments to strengthen the innovation and investment potential of the industry and strengthening export potential. Calculations are based on data from the State Statistics Service of Ukraine (2023; 2024), the Ministry of Agrarian Policy and Food of Ukraine (2024a), and the Ukrainian Institute of Plant Variety Expertise (n.d.).

► Results and discussion

The production of conditioned seeds is a key prerequisite not only for the renewal of crop production but also for increasing crop yields. The efficiency of agricultural production is significantly affected by the quality of the varieties and hybrids sown. Therefore, it is necessary to create innovative high-quality varietal resources and use the most effective ones. The main objectives of the seed industry are to increase the number of crop varieties and hybrids to meet the maximum social needs; increase their yields; improve the quality characteristics of agricultural products; and use simplified growing and harvesting technologies. In the breeding process, the above-mentioned areas of crop improvement are addressed systematically, and optimisation of the value chain of seed production in Ukraine, including proposals for the main areas of investment in the development of breeding seed production, will allow for more efficient operations.

In the period 1990-2024, plant breeding and seed commercialisation gained significance at the global level. Crop breeding has become a priority activity of global multinational corporations focused on the production of conditioned seeds, which has led to conflicts, disputes and lobbying for the protection of intellectual property rights in seeds. The high complexity of assessing the advantages and disadvantages of different regimes for the protection of intellectual property rights in the seed sector has led to a decrease in attention to them. A proper and balanced approach to assessing this important issue involves removing political obstacles, ranging from comparing the appropriateness of patents and special forms of intellectual property protection as a factor in stimulating innovation to ethical and moral aspects (Campi & Nuvolari, 2015).

During the same period, the seed industry also grew steadily. Several changes occurred: improved market organisation, increased contract trading, increased mechanisation of agriculture, easier access to credit, increased exports, use of plant protection products, mineral fertilisers and high-yielding seeds, and the growing importance of private business in processing, branding, marketing and other activities. The government has taken many progressive and reformist steps to increase the importance of the seed sector in the country's economy.

The Ukrainian seed system operates in a highly competitive market environment and is aimed at increasing agricultural production and ensuring food security (Novikov *et al.*, 2021). The main activities of the system are the breeding and multiplication of Ukrainian varieties, import and multiplication of foreign varieties, variety testing and registration, issuance of certificates for seed products, etc. (Table 1). The first subsystem is aimed at ensuring the in-

novative development of seed production and the creation of new plant varieties; the second subsystem provides state qualification expertise; the third subsystem ensures the production and propagation of certified seeds; and the fourth subsystem is responsible for variety certification and monitoring compliance with seed production standards. All system entities are directly subordinated to the Ministry of Agrarian Policy of Ukraine.

Table 1. Structure and functions of the system of conditioned seed production of grains, oilseeds and pulses in Ukraine

Seed production subsystem	Subjects	Functions and objectives
Innovative development of seed production and breeding	Research institutes and breeding research stations, breeders – authors of varieties, patent holders	Development of new varieties based on innovative technologies and their primary propagation
State qualification examination of plant varieties	Ukrainian Institute for Plant Variety Examination (UIPVE) and its branches	Testing, expert evaluation and registration of varieties
Production and propagation of agricultural plant varieties	Research institutes, experimental stations and farms of educational institutions, private enterprises registered in the State Register as producers of seeds and planting material	Production of supplementary, basic and certified seeds
Varietal certification and control over seed production	Authorised state and private enterprises	Direct field inspections, seed quality checks, certification of farms and monitoring of compliance with production standards

Source: developed by the authors

The need to create sustainable high-yielding hybrids adapted to the soil, terrain and climate conditions of a particular area is driven by modern demands. However, not all farmers are ready to experiment and prefer to buy old, time-tested hybrids. Solving the problems associated with low variety adoption and slow turnover requires new knowledge about the impact of individual demand factors in the seed value chain to determine the conditions for farmers to make the best decision when purchasing seeds, as well as to identify marketing risks inherent in new products by seed producers and sellers. P. Rutsaert *et al.* (2024) emphasise that the source of information on the effectiveness of a new hybrid or variety is the results of farmers' experiments with them, and that closer interaction between agricultural enterprises on the one hand and seed producers and sellers on the other is needed to intensify these experiments.

To prevent financial losses due to insufficient or excessive seed production, producers must respond quickly to changes in demand and constantly monitor their state. The production planning process is based on information about the timing of sowing, the area under crops, the demand for seeds, the dynamics and future trends, and the government support programmes that producers can participate in. Sources of information can include offic-

es of agricultural producers, trade organisations, internet searches, seed centres, etc. (Qadir *et al.*, 2024).

Seed producers need to be aware of the state of demand for seed products. Over- or under-production can have serious financial consequences for seed producers. Information on seed demand is crucial for producers when planning seed production. To plant seed production, they need to obtain information on the area under cultivation, the sowing season, seed demand (variety, quantity, location and time) in previous and subsequent years and government programmes. They can obtain this information from a variety of sources, including private search, agricultural offices, agricultural shops, SCAs (e.g. Badan Pengawasan dan Sertifikasi Benih [Seed Control and Certification Bureau]) and seed centres (Qadir *et al.*, 2024).

Indicators characterising the state of seed production of major crops (cereals, oilseeds) in Ukraine are shown in Table 2. These include: the equivalent value of seeds – about 70.0 billion UAH; seed turnover – 55.0 billion UAH; seed production – 2.3-2.5 million tonnes; about 50 seed plants and 500 seed producers; the number of varieties and hybrids – approximately 5.0 thousand; the number of varieties for which primary seed production is carried out – only 3.2 thousand varieties Ministry of Agrarian Policy and Food of Ukraine (2024a).

Table 2. Indicators of functioning and development of Ukrainian seed production of grains, pulses and oilseeds in Ukraine as of 01.01.2024

Metric	Value
Seed value, billion UAH	69.5
Seed turnover in Ukraine, billion UAH	55.0
Annual investments, billion UAH	up to 10.0
Production volume, thousand tonnes	~ 2,400
Seed production entities, units	~ 500
Seed plants, units	~50

Table 2, Continued

Metric	Value
Varieties and hybrids, units	5,000
Primary seed production (management), units	3,200
Export, million USD (seeds exported)	77.0
Import, million USD (seeds imported)	350.0
Royalties paid annually, million UAH	80-100
Potential royalty value of nationally bred varieties, million UAH	900.0
The potential value of breeding payments, million UAH	700-750

Source: calculated by the authors

Seeds of grains, pulses and oilseeds account for a significant share of about 10-12% in the structure of costs to produce grains, pulses and oilseeds (Table 3). In 2015-2023, agricultural producers' expenditures on seeds in value terms increased more than tenfold compared to 2010. In 2023, the cost of seeds increased to 55.0 billion UAH, which corresponds to the growth rate of total costs per hectare of arable land over these years. Total expenditures also increased by more than 10.6 times. In the analysed period, several factors contributed to the growth of seed costs. Firstly, the seed industry was undergoing intensification, which resulted in a simultaneous increase in the costs of producing seed and its quality. Secondly,

prices for inputs included in the cost of seeds increased, and thirdly, the share of purchased seeds in the total volume of seeds increased. Agricultural producers value their seeds at cost, while purchased seeds are valued at the purchase price. At a time when the seed industry is becoming more specialised, the share of seed used by agricultural enterprises is increasing, it is taking on a commodity form, and the calculation of seed costs at average cost does not meet the requirements of seed production development. In such circumstances, the reporting materials of agricultural enterprises cannot be an objective basis for comparing production efficiency when using owned and purchased seeds.

Table 3. Dynamics of costs of production of grains, pulses and oilseeds and the place of seeds in 2010-2023

Expenditure	Year							
	2010		2015		2020		2023	
	billion UAH	%	billion UAH	%	billion UAH	%	billion UAH	%
Salary	4.3	8.6	7.9	5.1	18.1	6.5	38.0	7.1
Contributions to social activities	1.5	3.0	2.8	1.8	4.0	1.4	8.4	1.6
Seeds	6.1	12.2	18.4	11.8	27.4	9.8	55.0	10.3
Mineral fertilisers	8.1	16.1	29.1	18.6	45.9	16.5	142.3	26.8
Petroleum products	6.7	13.3	18.3	11.7	22.2	8.0	64.8	12.2
Current repairs	3.0	6.0	10.8	6.9	14.7	5.3	17.7	3.3
Amortisation	3.0	6.0	7.5	4.8	24.6	8.8	53.3	10.0
Payment for services and works	8.1	16.1	30.0	19.2	24.0	8.6	12.6	2.3
Other expenses	9.4	18.7	31.5	20.1	98.1	35.1	140.9	26.4
Total	50.2	100.0	156.3	100.0	279.0	100.0	533.0	100.0

Source: calculated by the authors and data of the State Statistics Service of Ukraine (2021)

The economic efficiency of seed production directly depends on the costs incurred for breeding activities. Objectively speaking, the production of additional seeds for all crops is quite costly. At the same time, additional seeds have the best yield potential, as they contain all the valuable genetic properties of the variety. Therefore, the price of additional seeds of cereals, pulses and oilseeds is formed considering the valuation of intellectual

property rights. The costs of producing additional seeds in scientific breeding institutions include all material costs to ensure the necessary organisational and technological conditions for breeding activities. Using the example of the Sinelnivskivska breeding and research station, the formation of the standard cost of seeds of spiked cereals can be analysed by stages of production of additional categories in 2023 (Table 4).

Table 4. Calculation of the standard cost of conditioned grain seeds*, 2023

Metric	Measurement unit	Nursery for the selection of elite plants	Nursery for testing offspring 1	Nursery for testing offspring 2	Propagation nursery 1	Propagation nursery 2
Area	hectare	-	0.1	0.2	1.2	8
Gross yield	kg	3,000 elite plants	200	800	4,800	32,000
Seed yield	kg		80	400	3,000	20,000
Used: for the insurance fund	kg	1,000 elite plants	40	200	1,500	-

Table 4, Continued

Metric	Measurement unit	Nursery for the selection of elite plants	Nursery for testing offspring 1	Nursery for testing offspring 2	Propagation nursery 1	Propagation nursery 2
for sowing (further reproduction)	kg	1,000 elite plants	400 families, 40 kg	200	1,500	-
Seeds	UAH	0	11,864	17,185	18,960	32,010
Remuneration and social contributions	UAH	11,864	20,740	16,758	22,399	34,014
Fuels and lubricants	UAH	0	747	1,494	3,984	26,560
Fertiliser application	UAH	0	1,200	2,400	14,400	96,000
Plant protection products	UAH	0	0	620	3,720	24,800
Current repairs	UAH	0	200	400	2,400	16,000
Depreciation and amortisation expense	UAH	0	120	260	1,560	9,800
Refinement of seeds	UAH	0	0	0	7,680	38,600
Total expenses	UAH	11,864	34,870	39,117	75,103	239,184
including seeds	UAH	11,864	34,371	37,917	69,703	203,184
Production cost of seeds, kg	UAH	×	429.64	94.80	23.23	10.16
Costs for certification of 1 kg of seeds	UAH	×	×	×	×	0.41
Production cost of 1 kg of additional seeds, total	UAH	×	×	×	×	10.57

Notes: * – in the units of the National Academy of Agrarian Sciences of Ukraine; × – data is not calculated

Source: data from the National Academy of Agrarian Sciences of Ukraine (n.d.)

State-owned research and breeding institutions that produce pre-basic seeds require significant amounts of funding. However, even the state budget funds cover no more than half of the costs of state breeding institutions. For instance, in 2023, the cost of producing 1 kg of seeds of the first generation of cereal crops at the Synelnykivska Selection and Research Station was 429.64 UAH. The structure of material costs changes according to the technological processes at different stages of production. At the same time, the output increases each year, so the cost per unit of production decreases significantly as gross costs increases. For instance, according to experts, the cost of producing 1 kg of seeds in the second year of propagation was 10.16 UAH. Additional costs are also incurred for seed certification, which involves seed control, including field inspection, sowing quality control, and soil (varietal) control. Per 1 kg of additional seed, these costs amounted to another 41 kopecks, or almost 4.0% of total seed production costs (Table 3). The primary task for the future is to increase solvency at the key links (initial and final) of the seed distribution chain from breeders to agricultural producers. This is a short-term task. Further, an increase in the supply of seeds without an increase in demand will increase carry-over stocks and lower prices on the domestic market. Only after the gradual resolution of the issue of increasing demand for seeds will it be possible to reorient the market management mechanism to increase the supply of seeds, reduce their cost, improve their quality and range, and control price declines. To do this, it is necessary to create a full-fledged infrastructure of the plant variety market, the elements of which would harmoniously and efficiently cooperate in the production and sale of seeds.

A. Qadir *et al.* (2024) identified a correlation between seed producers, their production and production

capacity, and institutional categories. The authors view the solution to production problems as promoting interagency coordination and network research related to testing and breeding new varieties and hybrids and developing seed production infrastructure to meet the ever-increasing demand. The sustainable agriculture system has four components: breeding of new varieties and technologies; production of new varieties of seeds and their distribution; certification of new varieties of seeds and quality control; and supporting components of the system such as legal regulation, financing, human resources, etc.

The institutional framework for the protection of intellectual property rights in the seed industry was studied by B. Charnley & G. Radick (2013). The authors insist on the settlement of disputes over the use of new varieties and their ownership between breeders and unscrupulous seed users. The scientists believed that it was unfair to consumers who threatened the profitability of new varieties. This issue has not lost its relevance for more than a century. Since 1900, scientists have been studying institutional mechanisms to protect the rights of breeders. In this regard, global legislation and/or patent practice is being revised due to challenges from agriculture, science and business. Protection of plant-related objects can be carried out by patenting a plant variety, patenting a utility model or patenting a plant (USA). Since utility model patenting does not provide the same protection as plant variety patenting, it is much more complicated. Such patenting is used in countries where patents are granted for higher forms of life and experimental support for it should be at a much higher level. At the same time, the scope of protection is gradually narrowing (Sechley & Schroeder, 2002).

Proposals for improving the Ukrainian seed industry by 2030:

Proposal 1. The efficiency of the seed industry will be enhanced by the creation of regional (oblast) seed production systems that will be focused on meeting the existing needs of agricultural producers, considering expected changes in the future. In this regard, it is necessary to create three organisational elements of the seed production system – a seed breeding centre, a seed enterprise and a regional association of seed producers.

As of 1 January 2024, there were 126 seed plants and seed facilities in Ukraine, including 46 seed plants (Ministry of Agrarian Policy and Food of Ukraine, 2024a). Therefore, each region can operate under the above scheme. At the same time, seed producers will be able to receive varietal seeds that have been cleaned, calibrated, treated and packaged following international requirements. This will allow Ukraine to create new opportunities to enter the international market, namely the European market, which is the most attractive and expensive.

The stability of the supply of seeds to agricultural enterprises is a key to national food security. Seed producers

and seed distributors play a crucial role in developing the seed production system, ensuring demand and increasing the supply of seeds, by introducing many varieties and hybrids into circulation and delivering seeds to consumers. The total volume of the seed market is measured by the number of seed available, its accessibility to consumers, and its price. Access to quality seeds is determined by the ability of agricultural enterprises to obtain them from official and unofficial sources. The availability of quality seeds is limited by low supply, high price and insufficient buyer's ability to pay. The criteria for accessibility of seeds for agricultural enterprises are the following indicators: the volume of production demand for seeds, ease of purchase and price adequate to the enterprise's capabilities.

To form the price of grain seeds and ensure the full functioning of the market environment, it is possible to calculate the standard cost, purchase price for the plant and selling price of 1 tonne of winter wheat seeds with the involvement of farmers in the region (Fig. 1). The calculation methodology is universal for cereals, legumes and oilseeds.

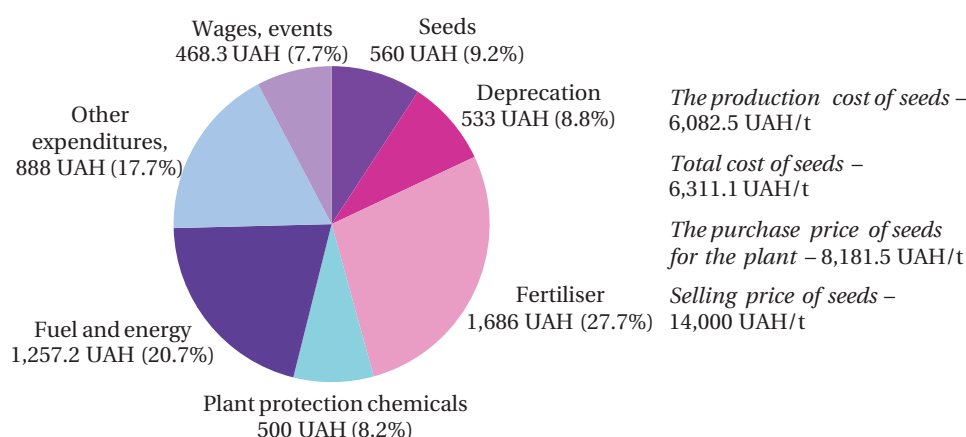


Figure 1. The structure of the standard cost and price of 1 tonne of winter wheat seeds for farmers, the purchase price for the plant and the selling price for agricultural producers as of 01.10.2023

Source: calculated by the authors

Strategic areas of development aimed at meeting the needs of agricultural production should include: the development of regional variety selection for specific natural conditions; ensuring the growth of the human resources of research institutions; balancing supply and demand using economic levers; and ensuring commercialisation and profitability of seed production. In developing countries, the share of seed products in the commercial seed market is quite small and often meets no more than 10% of the needs of agricultural enterprises (Qadir *et al.*, 2024).

At the current stage of seed production development, several issues of agronomic, technical and technological, socio-economic origin, etc., significantly addressed the volume of seed production and sales. In the process of creating and distributing seed value, the main ones are the lack of a well-developed national policy for the development of the industry and the formation of seed producers' income; low productivity of seed production and limited business access; limited horizontal links between actors and access to foreign markets.

A. Fugerey-Scarbel & S. Lemarié (2024) analysed the drivers of new variety development and marketing. The authors analysed all links in the value chain from breeding a new variety to the production of finished crops and their further processing. A comparison is made between the most common and minor crops – wheat and peas. Comparison of crops with different market sizes was used to track each link of value creation in the production and sales process through the impact of this parameter on each of the actors (breeding institutions, seed traders, agricultural enterprises, elevators and the processing industry). The influence of market size on the strategy of each of the actors involved in value creation is determined, which necessitates the inclusion of a mechanism of self-reinforcement through interaction between them.

Seed producers should retain a certain portion of the profit from the sale of seeds after harvesting, and send the seeds to processing companies that process, treat and package them. Royalties that will be paid in the future to the owner of the variety in the total costs of the seed plant were also included. The proposed scheme is shown in Figure 2.

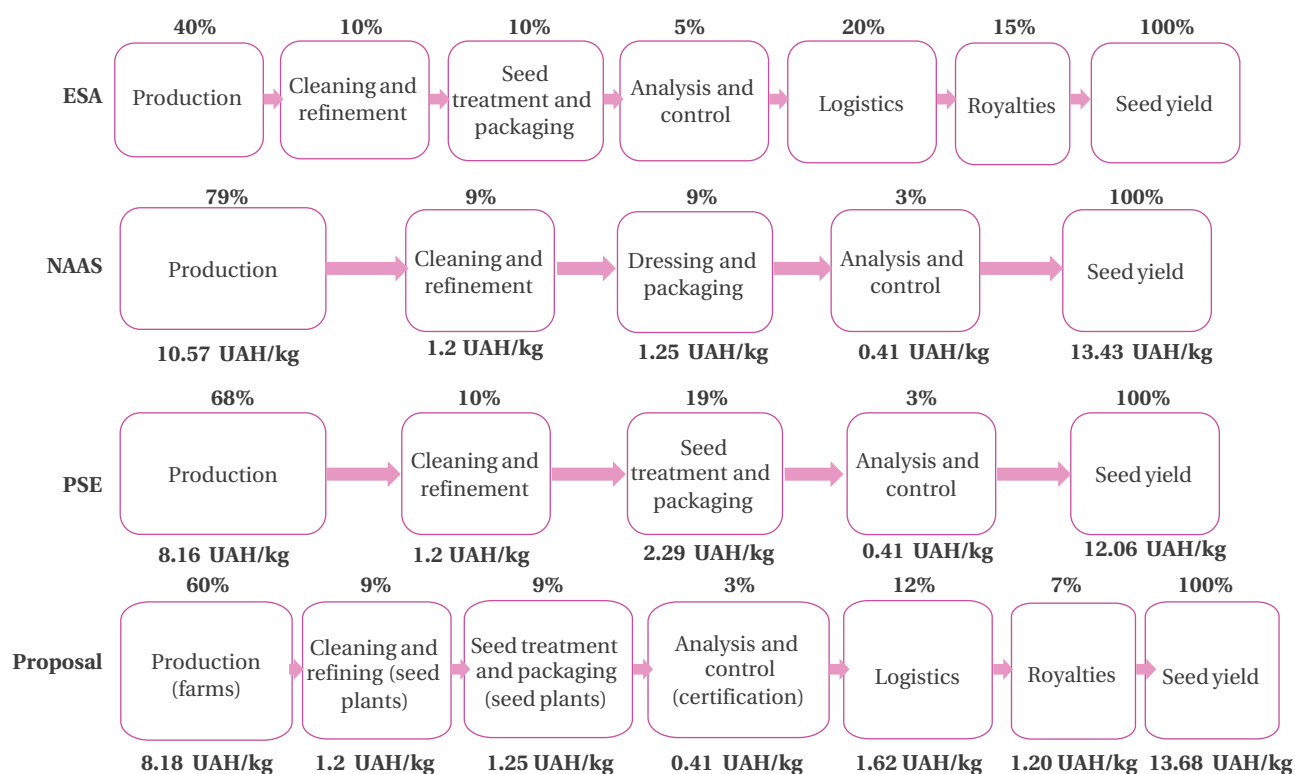


Figure 2. Actual and proposed value chains of conditioned seed production in Ukraine and the world

Notes: NAAS – National Academy of Agrarian Sciences of Ukraine; ESA – European Seed Association; PSE – private seed enterprise

Source: calculated by the authors

This will ensure the transition of seed production in Ukraine from artisanal to a more professional level. The use of the successful experience of European countries (Lazarieva, 2022) in supporting seed production will increase the solvency of producers and consumers of conditioned seeds at all stages of their marketing; develop a mechanism for managing the seed market to increase the supply of conditioned seeds, reduce their price, improve their quality and range; attract a significant number of farms to produce nationally selected seeds in different climatic zones of Ukraine; create regional (oblast) seed production systems, which should include a seed breeding centre, seed plant, and regional union of seed producers.

Proposal 2. Given the limited budgetary funding and protection of the interests of Ukrainian breeding centres and breeders, it should be mandatory to make royalty and breeding payments as the main investment component of further development of seed production of cereals, legumes and oilseeds. Based on its research, the European Seed Association (Euroseeds, n.d.) identifies royalties as a component of the main costs of selling conditioned seeds in the amount of 15% of total costs (Fig. 3). The other components are seed production costs – 40%, cleaning, processing, treatment and packaging – 20%, logistics – 20% and analysis and control – 5%.

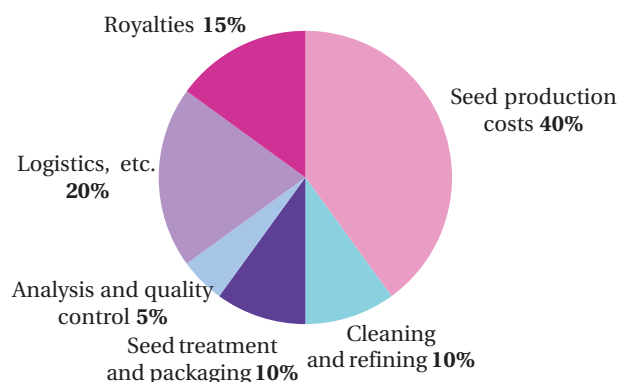


Figure 3. Cost components in the cost of conditioned seeds

Source: created by the authors based on The voice of the European Seed Sector (n.d.)

Analysing the main components of the cost of creating conditioned seeds, it is possible to note that the cost of seed production is only 40% of the total cost, the rest is added value. N. Kalaitzandonakes & A. Magnier (2013), E. Gimon *et al.* (2013), and Y.A. Yigezu *et al.* (2018) argue that the genesis of national seed systems is hampered by global challenges. Multinational companies have contributed to the monopolisation of the seed market by imposing excessive licence fees and controlling food resources at the global level. The result is overcharging farmers and having devastated environmental impacts on agriculture. The private seed companies that dominate the seed market are changing the goals of breeding programmes and setting new market trends. Their research in breeding activities is innovatively aimed at creating seed traits that would maximise their profits. This is primarily the creation of hybrids of profitable crops, such as vegetables.

Seed production is a highly profitable industry. Therefore, significant amounts of private investment are channelled into the seed business every year. According to the

Ministry of Agrarian Policy and Food of Ukraine (2024b), it is projected that the value of seeds will increase from 2.7 to 4.2 billion USD in 10 years. The average cost of seed in Ukraine will increase to 110 USD per hectare over this period, or 35% from the level of 2023 (80 USD per hectare). The construction of new seed plants alone is expected to attract 84.0 million USD of investment resources annually.

According to the authors of the study, investment support for seed production of cereals, legumes and oilseeds is up to 10.0 billion UAH, or approximately 300.0 million USD annually (Table 1). Potential royalty and breeding payments are presented in Tables 5 and 6. Annual payments for varieties of Ukrainian breeding amount to 80-100 million UAH, with a potential royalty of 5.2 billion UAH, of which about 800 million UAH from the use of seeds of Ukrainian breeding, which could be used for the development of breeding and the use of new varieties and hybrids. Therefore, annually, Ukrainian crop producers pay about 5.0 billion UAH to support and invest in foreign science that produces varieties of domestic selection.

Table 5. The cost of conditioned seeds and royalty calculation in Ukraine in 2013

Cultures	Seeds produced, thousand tonnes	Cost of seeds, million UAH	Area planted, thousand ha	Royalties, million UAH		Royalties per 1 ha of crops, UAH
				total	including those from Ukrainian breeding	
winter wheat	78.8	1182	394	118.2	56.9	300
spring barley	10.7	149.8	59.4	14.98	5.3	252.1
winter barley	12.2	170.8	67.8	17.08	3.5	252.1
corn	103	22,660	4,923.6	3,399	611.8	690.3
winter rye	5.9	82.6	32.8	8.26	1.0	252.1
buckwheat	0.7	28	8.8	2.8	2.8	320.0
millet	0.6	21	12	2.1	2.1	175.0
oats	0.9	12.6	5.0	1.26	1.3	250.7
triticale	0.4	5.6	2.2	0.56	0.6	252.5
spring wheat	5.3	74.2	26.5	7.42	1.7	280.0
peas	6.1	122	20.3	12.2	2.0	600.0
Total cereals	224.6	24,508.6	5,552.4	3,583.9	688.9	×
soy	22.6	678	188.4	67.8	4.5	359.9
winter rape	5.1	1,530	1,020	229.5	22.5	225.0
sunflower	35.7	8,925	5,100.0	1,338.75	89.7	262.5
Total oilseeds	63.4	11,133	6,308.3	1,636.1	116.7	×
Total	288	35,641.6	11,860.7	5,219.9	805.5	×

Notes: × – data is not calculated

Source: calculated by the authors based on data from the Ministry of Agrarian Policy and Food of Ukraine (2024a)

Table 6. Amounts of royalties and breeding payments for grains, oilseeds and pulses (based on the example of 2023 sowing) in Ukraine

Cultures	Royalties per 1 ha of crops, UAH	Breeding payments per 1 ha of crops, UAH (50% of royalties)	The area where selection payments can be made, thousand hectares	The potential annual amount of selection payments, million UAH
winter wheat	300.0	150.0	2,971.1	445.7
spring barley	252.1	126.1	198.7	25.0
winter barley	252.1	126.1	366.6	46.2
winter rye	252.1	126.1	5.9	0.7
buckwheat	320.0	160.0	106.9	17.1
millet	175.0	87.5	66.9	5.9
oats	250.7	125.4	47.4	5.9
triticale	252.5	126.3	3.2	0.4

Table 6, Continued

Cultures	Royalties per 1 ha of crops, UAH	Breeding payments per 1 ha of crops, UAH (50% of royalties)	The area where selection payments can be made, thousand hectares	The potential annual amount of selection payments, million UAH
spring wheat	280.0	140.0	112.7	15.8
peas	600.0	300.0	117.9	35.4
soy	359.9	180.0	1,475.2	265.5
Total	×	×	5,472.5	863.6

Notes: × – data is not calculated

Source: calculated by the authors according to the Ministry of Agrarian Policy and Food of Ukraine (2024), State Statistics Service of Ukraine (2024)

In addition, the transition to breeding payments could additionally provide Ukrainian breeders with over 700 million UAH, even if breeding payments are no more than 50% of the royalty value. Comparing France, Germany and Ukraine – countries with similar crop areas – the amount of royalties paid is very different. Annually, 125 million euros are paid in royalties and breeding fees in France, 65 million euros in Germany, and only 2.5-3 million euros in Ukraine (Zakharchuk *et al.*, 2024). Compared to European countries, royalty and breeding payments in Ukraine are virtually non-existent and payments for intellectual property protection are several times lower.

There are no state programmes to support the development of Ukrainian breeding and seed production of cereals, pulses and oilseeds. State programmes to finance plant breeding were in place only until 2011. In 2018-2019, the Programme “Partial compensation (80%) of the cost of seeds of agricultural plants of Ukrainian breeding purchased from seed producers of the basic, certified category (excluding VAT, but not more than 80 thousand UAH per farm)” was in effect but was cancelled by Resolution of the Cabinet of Ministers of Ukraine No. 106 (2018). This may lead to a reduction in the share of Ukrainian varieties on the seed market. Nevertheless, there is a need to improve the process of collecting licence fees, depending on the actual consumption of seeds under licence and sublicense agreements and breeding fees for Farm Saved Seed – seeds for in-house use.

Using the Canadian (French) mode of collecting breeding fees (per tonne of marketable grain sold), the Polish or German scheme (per 1 ha of marketable crops) as a basis, in any case, revenues to breeders and breeding institutions could amount to between 0.7 and 1.0 billion UAH. At the same time, each owner of a variety should be guaranteed protection of its intellectual property. For this purpose, agricultural producers need to declare varietal production crops, register licensing agreements and collect royalties, and control, form and maintain a database of seed and commercial crops by varieties and hybrids. This will help to increase the flow of investment resources to produce new high-yielding varieties of Ukrainian breeding.

For the restoration of Ukrainian breeding and the future, including proposals for optimising the value chain of seed production in Ukraine and the main areas of investment in the development of breeding seed cultivation/production, it is necessary to improve the technical and technological support of breeders and scientific breeding institutions, develop recommendations on modern

technologies for growing seeds in different natural and climatic zones of the country; improve the legal and organisational aspects of the activities of NAAS research institutions based on public-private partnership; gradually adapt Ukrainian seed production to global requirements for seed production and certification, join all OECD seed modes; strengthen the export potential of Ukrainian seeds of national selection, increase their competitiveness and eliminate bureaucratic and logistical barriers to the supply of seeds to the global market.

► Conclusions

The study substantiated that the creation of a sustainable investment and innovation seed system is necessary to create new varieties of crops to meet the needs of agricultural enterprises. The study determined that 496 seed production entities operate in the Ukrainian seed system, including 46 seed plants. In 2023, the register contained 5,000 seed varieties and hybrids, and only 3,200 of them were used for primary seed production. The volume of seed imports in terms of value is 4.5 times higher than exports and in 2023 amounted to 350 million USD.

The calculations confirmed that in the structure of the standard cost of seeds of additional categories, the largest share is accounted for by mineral fertilisers (22.8%), fuels and lubricants (20.1%), rent for the use of land plots (10.8%), seed material (9.2%) and depreciation of fixed production assets (8.8%). It is proved that in the structure of the value added of conditioned seeds, the largest share is made up of seeds that come from the enterprises that grow them for processing. For enterprises that are members of the European Seed Association (EU countries), this share is 40%, institutions of the National Academy of Agrarian Sciences – 79%, and private enterprises – is 68%, according to the authors' calculations, this share should be optimally 60% for Ukraine. Other components of value added are less significant in the final price and account for 5-10% of the total value added. At present, neither the institutions of the National Academy of Agrarian Sciences nor private enterprises of Ukraine include royalties and breeding payments in the total cost of conditioned seeds.

According to the calculations, the potential royalties from the use of conditioned seeds of cereals, pulses and oilseeds could amount to 5.8 billion UAH, including approximately 900 million UAH for Ukrainian varieties. The estimated potential amount of breeding payments could be over 700 million UAH. This is a substantial investment that could become innovative in supporting Ukrainian breeders. Ukraine could become one of the most

innovative countries in the genetic, breeding and seed sector with significant achievements in the protection of plant variety rights in terms of intellectual property, but a more detailed review of these issues will require further research in the future.

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None.

►Conflict of interest

None.

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Інвестиційно-інноваційний розвиток насінництва України в умовах вступу в Європейський Союз

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► **Анотація.** Метою статті була оцінка інвестиційно-інноваційного забезпечення насінництва, розробка заходів з підвищення ефективності й пропозицій захисту прав селекціонерів щодо отримання роялтих та селекційних платежів. У дослідженні використано монографічний, економіко-статистичний, табличний та графічний, емпіричний, порівняльний аналіз, прогнозування, абстрактно-логічний методи. У результатах статті розглянуто організацію і функціонування насінневої галузі в Україні. Досліджено основні показники розвитку насінництва зернових, бобових та олійних культур, виявлено випереджальні темпи розвитку імпорту над експортом і, відповідно, імпортна надзалежність України, що призводить до вразливості на світовому насінневому ринку. Узагальнено динаміку витрат на виробництво насіння зернових, олійних та бобових культур, розраховано нормативну собівартість насіння пшениці. Розроблено пропозиції щодо захисту прав селекціонерів в частині захисту прав інтелектуальної власності на сорти рослин, враховуючи передовий досвід європейських країн. Побудовано фактичні та запропоновано власні ланцюги доданої вартості виробництва кондиційного насіння в Україні. Найвагомішими показниками зростання насінництва в Україні є обсяг посіву (2300-2500 тис т.), експорт (77 млн дол. США), імпорт (350 млн дол. США). В структурі собівартості всіх виробників найбільшу частку становить виробництво насіння, яке надходить на підприємство на доробку (40-80 %, залежно від категорії виробників). Обсяг сплаченого роялті щорічно становить в середньому 90 млн грн. при потенційно можливому 900 млн грн. Селекційні платежі в Україні не сплачуються взагалі, хоча могли б становити 725,7 млн грн

► **Ключові слова:** кондиційне насіння; собівартість; комерціалізація; селекційні установи; додана вартість; оптимізація



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Strategic vectors of agribusiness development in Ukraine

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► **Abstract.** In the current conditions of war, the formation of strategic vectors of agribusiness in Ukraine is an integral part of economic development in the post-war recovery. The purpose of this study was to identify the tasks that will provide opportunities to eliminate the negative trends caused by the war. The study conducted a bibliometric review of scientific papers on agribusiness in Ukraine and the world. Such an analysis helped to track trends, identify gaps and unresolved areas for further research, and formulate strategic vectors for the development of the agricultural sector. The study substantiated changes and trends in agribusiness in Ukraine as a result of the comparative dynamics of Ukraine's share in global agricultural exports. The paper focused on the specific features of exports during the Grain Initiative and identified the key continents of exports. It was found that the key problems faced by the agricultural sector in Ukraine include the unstable geopolitical situation, martial law, environmental changes, labour force shortages, and rapid globalisation. International agribusiness activities have undergone dramatic changes caused by the full-scale invasion. That is why Hoshin Kanri's strategic model for the development of Ukraine's agribusiness during the war and post-war recovery allows identifying key factors, forming trends, and anticipating risks affecting agribusiness. The proposed strategy also accommodates the need for the necessary resources to implement innovations and attract investment. This will improve the organisational design of agribusiness-oriented enterprises. The formation

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of an agribusiness development strategy should be aimed at spreading innovations in agribusiness and the greatest involvement of enterprises in this area in innovative activities. The findings of this study can be used in the activities of agricultural enterprises

► **Keywords:** agrotechnology; agro-industrial complex; agroholdings; agribusiness ecosystem; export; grain initiative

► Introduction

A special subsystem of economic relations, such as agribusiness, has emerged relatively recently as a result of the combination of agrarian, industrial, and trade capital in the integration of industry and agriculture. The development of agribusiness in any country, as well as the improvement of its sectoral and territorial structures, contributes to the rationalisation of production, efficient distribution and use of resources and raw materials, ensuring the country's food security and the development of international activities. A turning point in the development of agribusiness was the full-scale invasion of the country, which resulted in the extensive loss resources and damaged or destroyed infrastructure. Many elevator capacities have been partially or completely destroyed or are located in uncontrolled territory (under occupation). In the global market, Ukraine has always been a key exporter of raw materials, and most of its products were transported using maritime logistics routes. From 2022, the hostilities have significantly restricted this mode of transport, leading to a global redistribution of trade flows to commodities such as base metals, mineral oils, and agricultural products (Bentley *et al.*, 2022). World trade, as well as the global economic outlook, has suffered significant damage as a result of the Russian military invasion of Ukraine (Ruta, 2022).

Agribusiness in Ukraine has undergone a transformation due to the war, climate change, environmental degradation, rising costs, and declining profitability from major crops. Businesses with livestock as a key activity have faced problems with access to necessary resources such as feed, medicines, or equipment. There is a shortage of labour, rising prices for electricity and fuel and lubricants, dependence on electricity supply schedules, and a general shortage of electricity. Researchers increasingly often focus their studies on the economic consequences of the Russian-Ukrainian war (Polinkevych, 2024). M. Behnassi & M. El Haiba (2022) considered food security issues in the context of military conflict, as they weaken the country's and nation's potential, impeding the cultivation and harvesting of crops, processing, transportation, and supply to the market. K. Mahlstein *et al.* (2022) examined the issue of economic development in wartime, with a key focus on the use of sanctions as a coercive tool for shaping international policy. Y. Fang & Z. Shao (2022) focused on the changes that commodity markets experience from the negative impact of war: shortages, food crisis, price increases, currency fluctuations.

Due to the military actions in the country, agricultural enterprises are experiencing challenges in providing agricultural resources, such as seeds, fertilisers, and pesticides. Agribusinesses must diversify by looking for new types of activities, as well as change markets and find new buyers. T. Glaubien *et al.* (2022) focused on grain market analysis

and food security measures, M.A.R. Estrada & E. Koutronas (2022) addressed the effects and consequences of economic sanctions on trade. The recovery and development of agricultural business in Ukraine requires the development of effective strategic decisions. This is a rather lengthy process that depends on financing and attracting foreign investment, finding innovative approaches to agricultural activities, and securing stable export routes and logistics flows. The post-war recovery of agriculture in Ukraine means the development of agricultural technologies that will contribute to the efficient and rational use of resources, automation, increased competitiveness, and improved market relations and the economy of Ukraine overall (Shults & Lutskiv, 2024). N. Skorobogatova (2023) considered the ecosystem of agribusiness as a way to a balanced recovery of the agrarian economy of Ukraine, while S. Zakharenko *et al.* (2021) presented approaches to the strategic management of the agro-industrial complex, which are effective for implementation during the post-war recovery of the country.

The purpose of the present study was to formulate strategic vectors for the development of agribusiness in the context of war and during the post-war reconstruction of the country. Based on this purpose, the study solved the following tasks:

- conducting a bibliometric review of literature sources to identify key clusters and research areas on agribusiness in Ukraine and the world;
- substantiation of changes and trends in agribusiness in Ukraine;
- development of the Hoshin Kanri strategic model for the development of agribusiness in Ukraine during the war and post-war recovery.

► Literature review

The scientific basis for business process management is reflected in all areas of economic activity. The agrarian sector of the economy is no exception, which was later transformed into a separate area, namely agribusiness. In the first half of the 1950s, the term "agribusiness" was first mentioned in scientific studies as a vertical integration of activities. H.J. Davis & R.A. Goldberg (1957) were among the first to define agribusiness as a system of combined operations for the production and distribution of goods in the agricultural sector. The key areas of agribusiness are production operations on the farm, storage, and processing of agricultural products and finished goods. Thus, the concept of agriculture has acquired a new vector and expanded its scope. A little later, G. Sykes (1963) published a paper describing agribusiness as a close relationship between agriculture and industry, which jointly focus on the processing and marketing of agricultural products.

Over time, a new vector and approach to the concept of agricultural management has become increasingly popular. The production, processing, manufacture of agricultural goods and trade development as areas of agribusiness have become an economic sphere of activity for countries and a new area of research for scientists. J. Baran & J. Žak (2014) presented an analysis of transport activities carried out in different agribusiness entities, which resulted in a general rating of transport units operating in the considered agribusiness enterprises. The researchers defined a coherent system of criteria that allows evaluating transport activities in agribusiness, including both universal advantages and specific features of transport. An evaluation matrix was built and a rating of 10 transport units was formed.

I. Kovalchuk *et al.* (2021) considered the legal regulation of agribusiness as a relatively new area of activity, while Ya. Pushak *et al.* (2021) described the benefits of an economic security assessment system that determines macroeconomic sector trends. T. Gagalyuk *et al.* (2021) identified the benefits of corporate social responsibility in the activities of agricultural enterprises, which is significant in meeting the defined sustainable development goals for the period up to 2030. O. Demchenko *et al.* (2023) investigated the determinants of human capital development in the context of global challenges. Within the framework of the presented study, the literature review covered papers with a special focus on the agribusiness of Ukraine in the context of the war that began in 2014 and intensified after the full-scale invasion by Russia in February 2022.

A. Mazur *et al.* (2018) examined the issues of organisational reform of the agro-industrial complex to optimise them to meet the requirements of an advanced model of agricultural economic development. The significance of this topic is determined by the content and vector of systemic transformations in the agricultural sector of the economy aimed at forming a competitive and economically attractive management system. Some components of the presented model are also relevant for the strategy of agribusiness development in Ukraine in the post-war period. K. Nazarova *et al.* (2020) studied the trends in the development of the agricultural market of Ukraine. The researchers proved the significance of the agricultural sector for the national economy by considering its share and dynamics in GDP formation, the balance of key indicators in the agricultural market, and the necessity of attracting investors. However, the conclusions presented have lost their relevance due to the occupation of certain territories of the country and the mining of agricultural fields, which will require humanitarian demining.

That is why the study by L. Shovkun-Zablotska *et al.* (2024) is relevant, where the researchers chose the development of areas and tools for managing agricultural enterprises in the context of war in Ukraine as the purpose of the study. The objectives of the study were to develop a mathematical model of the operational change of the goal of an agricultural enterprise, to establish the conditions for changing the goals of agribusiness, to determine the wartime requirements for agribusiness management and to assess the impact of the war on the components of the resource potential of agricultural enterprises.

G. Fernandes *et al.* (2023) focused on the consequences of the armed conflict for shipping, which is indispensable for export-import operations of agricultural products. This article presented a quantitative assessment of the effects of the Russian invasion of Ukraine on various possible transport chains and the search for alternatives. A methodology for estimating the transport of agricultural products from Ukraine to a North African port was presented. The main conclusion of the study was that the costs for alternative transport chains increased at least twice.

E. Ribašauskienė *et al.* (2024) examined the most relevant strategies to ensure the resilience of the agricultural supply chain in the face of disruptive events. Innovation, cooperation, diversification, and knowledge accumulation are assessed as possible agribusiness strategy options. R. Goyal & S. Steinbach (2023) investigated the changes in the futures market in the wake of the Russian invasion of Ukraine and the Black Sea Grain Initiative. The study estimated that agricultural futures prices were 16% higher than hypothetical prices during the first nine weeks after the full-scale invasion. In contrast, the Black Sea Grain Initiative did little to change traders' perceptions of agricultural commodities in relation to the uncertainty of the futures market caused by the Russian-Ukrainian war.

In the analysis of trade in grains and oilseeds, S. Ahn *et al.* (2023) found that imports from Ukraine were 78.2% lower between February and July 2022. The researchers showed that the Russian-Ukrainian war had significant trade implications for the countries directly involved, but only limited ones for the global grain and oilseed markets. N. Volkova *et al.* (2023) studied the quality and competitiveness of agricultural products and agricultural enterprises in the context of Russian military aggression. The researchers proved that agribusiness needed an effective strategy and management approaches in wartime. O. Garafonova *et al.* (2023) analysed the damage caused by the war to Ukraine and agribusiness specifically. The researchers analysed the distribution of losses in the agricultural sector of the economy, including agricultural machinery, grain storage, livestock, and raw materials. The researchers also identified the principles of recovery after the war, which included gradual development, integration into the EU, investment promotion, creation of agricultural holdings, and cluster development of agricultural activities.

Y. Miao & T. Kharchenko (2023) focused on the development of an innovative strategy for managing agribusiness in the context of globalisation, while A. Mykhailov *et al.* (2021) developed investment tools for managing innovations in agribusiness. Thus, the analysis of the literature showed that agribusiness in wartime is a relevant area of interest for researchers in various fields, countries, and institutions. That is why it is important to conduct a bibliometric review in this area to identify scientific clusters and trends in the field of agribusiness.

► Materials and methods

The methodological framework of this study was formed by general and special scientific approaches and methods. The general scientific approach was the basis for the formation of prerequisites, trends, and patterns in the sustainable development of agricultural business. The

dialectical approach helped to formulate the philosophical aspects, factors, and conditions of agribusiness during the war. Based on the critical (evaluative) approach, the contradictions, critical aspects, and paradoxes of business focused on the strategic vectors of agribusiness development were identified. The application of systemic and synergistic approaches helped to form a holistic view of the formation of the agribusiness strategy of Ukraine.

The development of quantitative research was largely driven by the availability of modern bibliometric databases that provide information on publications and their citations. A bibliometric database contains bibliographic information about scientific publications on agribusiness and allows tracking their citations. Each of the existing databases has its specific features, set of functions, capabilities, and limitations. To study agribusiness issues, the study chose the Scopus scientometric database, which allows analysing scientific literature (and through it, the academic community) by a series of quantitative indicators, such as the number of publications, citations, number of co-authored papers, and complex production indicators. The bibliometric method was also employed to analyse the literature in the Scopus database. The analysis did not include any restrictions on the language of publication or country. In addition, no time limits were set for the period of publications, since the subject of agribusiness is relatively new, and the total number of papers ($n = 8,710$) does not exceed the limits set by the Scopus database. To assess the authors' influence, the profiles of individuals automatically generated by the Scopus database based on maximising publications were analysed. The presented profiles allow comparing authors by the number of publications, number of citations, and Hirsch index level. Information for the documents that met the requirements was filtered by the keywords "agribusiness", "agribusiness AND strategy", "agribusiness AND Ukraine". The Scopus scientometric database, which was chosen as a basis, contained 8,710 papers (as of August 2024) on the keyword "agribusiness" since 2004. This is because agribusiness has recently emerged from the field of agriculture, yet it is becoming increasingly relevant every year.

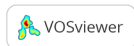
For the bibliometric analysis, the study used the online platform for monitoring and analysing international scientific research using visualisation tools and modern citation metrics of Scopus and the VOSviewer tool for building and visualising bibliometric networks. The application of the software helped to identify the principal links between existing data visualisation concepts and to identify new and little-studied aspects in the field of agribusiness. The map developed using VOSviewer software clearly demonstrates the frequency of terms that are used at least five times in publication titles, abstracts, and keywords, as evidenced by the size of the circle and the font size of the term. Thus, the larger the circle, the more publications contained the term associated with the keyword. Based on the colour, one can determine the belonging to a certain cluster of interrelated terms. Network visualisation displayed a system of interconnected terms (the closer they are to each other, the greater the level of semantic proximity) both within the same cluster and between clusters. The lines depicted on the map reflected the connections between individual keywords. Thus, the results of the

study allowed forming clusters, each of which combined a different number of thematically close keywords with varying frequencies of use and overall proximity of connection. The study also applied the Hoshin Kanri methodology to formulate a strategy for Ukraine's agribusiness. The built model will facilitate the alignment of strategies at enterprises, as well as the improvement of business processes for cross-functional management. The study employed the authors' publications, which are mostly presented in the Scopus database, regulatory documents of the Ministry of Agrarian Policy and Food of Ukraine (2023), and reports of the Main Agribusiness Website (Agribusiness of Ukraine, n.d.).

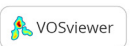
► Results

Agribusiness is a form of entrepreneurial activity in the agro-industrial sector of the Ukrainian economy. This sector includes business activities in the supply of inputs (fertilisers, machinery, seeds, and pesticides); agricultural production itself (crop and livestock production); processing, storage, and trade of raw materials and finished products. Notably, agribusiness includes certain types of activities related to the agricultural sector, such as market infrastructure and agro-services. To fulfil the purpose of the study, a network map of interconnections was built using the keyword "agribusiness", which helped to identify key scientific clusters that reflect the features, advantages, and disadvantages of agribusiness (Fig. 1). The mapping of interrelationships using VOSviewer software revealed that agribusiness issues are reflected in 18 scientific clusters. The clusters presented in Figure 1 demonstrate that agribusiness is not a separate area of scientific and practical interest, but is interconnected with logistics and management processes, territorial features, ecosystems and digital technologies, agriculture and food, economic and political features. Further study of the bibliometric data helped to build a network map of interactions in Figure 2. Thus, the greatest scientific attention to agribusiness was concentrated in the United States, Brazil, Indonesia, India, Germany, and Italy. The study of mutual citations between representatives of different countries shows a description of general trends in agribusiness, as well as an analysis of key issues in the world and global changes in the world economy. Out of the submitted papers, the Scopus scientometric database identified only 129 documents that address the issue of agribusiness in Ukraine. The bibliometric review helped to form a scientific portrait of the key authors, as it allowed analysing the number of published papers, citations, the author's h-index, as well as the titles of key and most cited papers (Table 1).

The diagnostics of the scientific portrait showed that the Scopus scientometric database does not contain a significant number of papers on agribusiness in Ukraine. Publications from 2021 onwards have become particularly popular, but there are virtually no papers describing the strategy for agribusiness development and prospects for the country's recovery in the post-war period. The study also found that by subject area, the largest number of publications belongs to Economics, Econometrics, and Finance ($n = 63$); Agricultural and Biological Sciences ($n = 48$); Business, Management, and Accounting ($n = 47$); Social Sciences ($n = 39$); Environmental Science ($n = 16$).



Source: compiled by the authors of this study based on scientific publications indexed by the international scientometric database Scopus using the VOSviewer tool



Source: compiled by the authors of this study based on scientific publications indexed by the international database Scopus, using the VOSviewer

Author name, affiliations, author profile	Total publications, including those on Ukrainian agribusiness	Citations by/h-index	Papers on the topic of agribusiness in Ukraine and number of citations in Scopus
Kucher, Anatolii V. Lviv Polytechnic National University, Lviv, Ukraine 57006415200	51/3	309/10	A. Kucher (2020) – 7 L. Pronko <i>et al.</i> (2020) – 23
Basiurkina, Nataliya Odesa National University of Technology, Odesa, Ukraine 57217103580	5/2	24/2	O. Demchenko <i>et al.</i> (2023) – 2 Ya. Pushak <i>et al.</i> (2021) – 14

Table 1, Continued

Author name, affiliations, author profile	Total publications, including those on Ukrainian agribusiness	Citations by/h-index	Papers on the topic of agribusiness in Ukraine and number of citations in Scopus
Gagalyuk, Taras V. Leibniz-Institut für Agrarentwicklung in Transformationsökonomien, Halle, Germany 35117765300	28/2	287/12	T. Gagalyuk <i>et al.</i> (2021) – 3 T. Gagalyuk & J.H. Hanf (2009) – 9
Kharchenko, Tetiana B. Sumy National Agrarian University, Sumy, Ukraine 57203587295	9/2	36/3	Y. Miao & T. Kharchenko (2023) – 2 A. Mykhailov <i>et al.</i> (2021) – 3
Kovalchuk, Inna Lviv Polytechnic National University, Lviv, Ukraine 57219240814	4/2	4/1	I. Kovalchuk <i>et al.</i> (2021) – 1 I. Kovalchuk <i>et al.</i> (2020) – 1

Source: compiled by the authors of this study based on data from the Scopus database

A characteristic feature of agribusiness is that it is a combination of separate types of work and therefore covers the sowing and cultivation of primary raw materials, their processing, storage, and sale. Certain areas are confirmed to gain advantages through scientific research. However, the key conclusion of the bibliometric review was that there were virtually no studies that would focus on the agribusiness in wartime. After the full-scale invasion, some of Ukraine's agricultural products lost their

positions in global exports. This is because a significant area of land has fallen under occupation, and military operations are taking place on other lands (Fig. 3), which has led to the alienation of land involved in agribusiness. Despite these changes, Ukraine has managed to largely preserve its agribusiness and, in some cases, improve its position. Positive trends are driven by the recovery of exports, albeit not in full, and by production, which continued even during the war (Fig. 4).

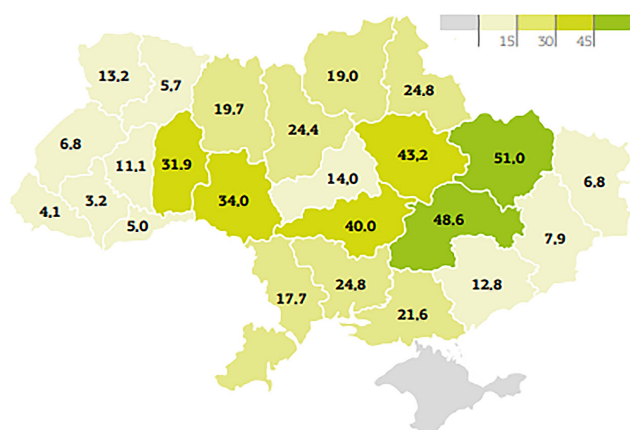


Figure 3. Area of alienated land in Ukraine due to war, by region, thousand ha (as of 31 October 2023)

Notes: total area – 492 thousand ha

Source: compiled by the authors of this study based on the infographic guide Agribusiness of Ukraine (n.d.)

An analysis of the data in Figure 4 suggests that agricultural products and their exports have hardly maintained their positions in the global market. Countries in different regions are dependent on Ukraine's raw material base and can only sustain their economies through imports. Changes in the trends of agribusiness in Ukraine have become a research interest for scholars. S. Ahn *et al.* (2023) considered the negative effects of the Russian invasion on global trade in grains and oilseeds, as well as major price fluctuations and threats to global food security. This situation has caused negative dynamics not only for Ukraine but also for many countries around the world. Countries such as Thailand, Iran, Bangladesh, and African

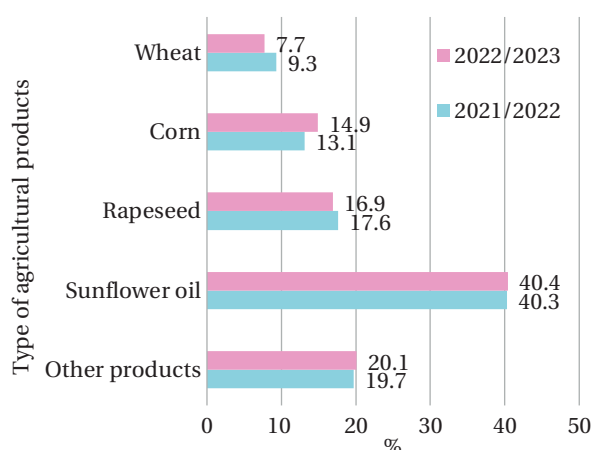


Figure 4. Comparative dynamics of Ukraine's share in global exports of agricultural products, %

Source: compiled by the authors of this study based on the infographic guide Agribusiness of Ukraine (n.d.)

countries have experienced a shortage of Ukrainian grain supplies, wheat and maize exports by India, and energy exports by European countries. This substantially affected the operations of agribusinesses due to disruptions in the resource management system.

A. Rose *et al.* (2023) described the disruption of grain exports and the emergence of a global food crisis as an economic consequence of the war. The results of the study were based on the analysis of the effects of the decline in grain exports and the deterioration of macroeconomic indicators in various regions of the world, as Ukraine is a key raw material base. Before the war, the main logistics for Ukrainian farmers was sea transport,

but the blockade of ports caused devastating damage and required the search for effective levers to overcome the situation. The best alternative was the creation of the Grain Initiative in August 2022, which became critically significant for Ukraine and enabled it to export

32.9 million tonnes of products (Fig. 5). In their study, H.M. Ay & A. Söylemez (2023) proved the benefits and significance of the Black Sea Grain Initiative for Ukrainian grain exports and analyse Turkey's policy when signing this agreement.

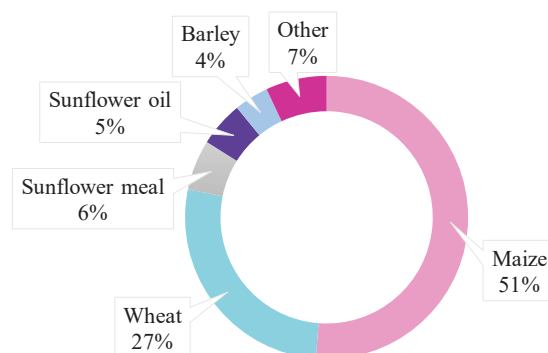


Figure 5. Ukraine's top five export commodities during the Grain Initiative, million tonnes

Source: compiled by the authors of this study based on the infographic guide Agribusiness of Ukraine (n.d.)

Only partial replacement of maritime transport by road is possible, but port infrastructure cannot be replaced. Despite the adaptation of agribusiness to new realities, farmers still cannot fully perform their work and face sales problems due to the constant shelling of

border areas, infrastructure, and border blockades initiated by neighbouring countries. Another convincing factor in the development of Ukraine's agribusiness is the results of exports during the Grain Initiative, where the main consumers are Asia, Europe, and Africa (Fig. 6).

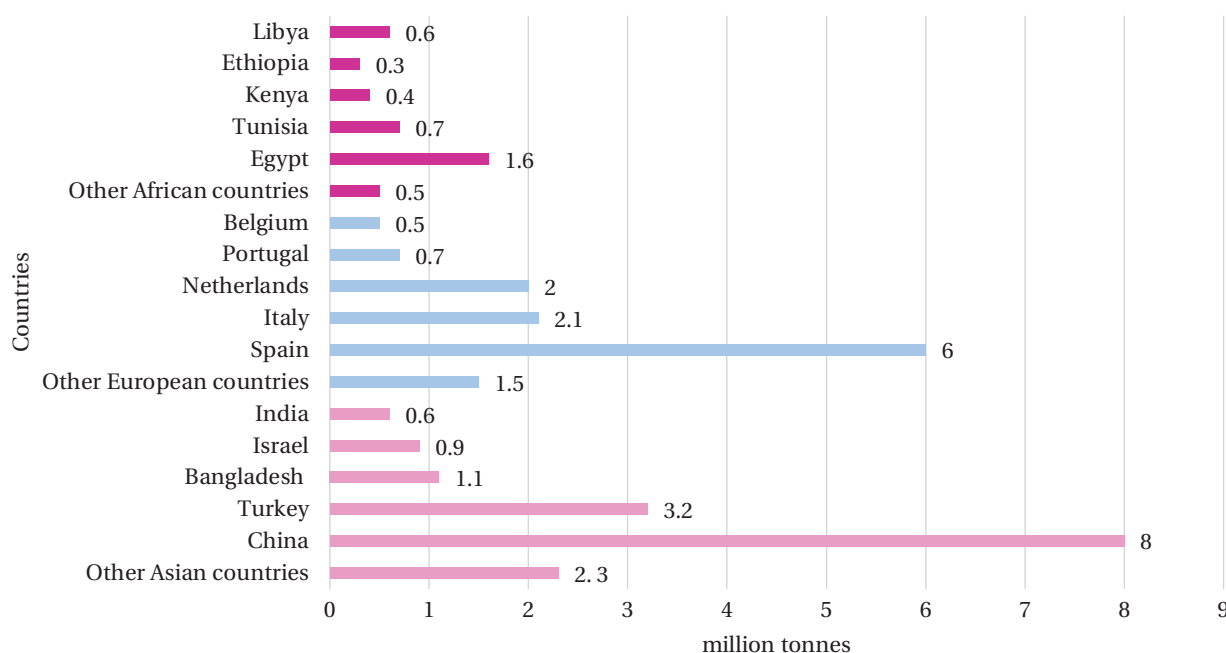


Figure 6. Geographical structure of exports during the Grain Initiative in 2022-2023, million tonnes

Source: compiled by authors of this study based on the infographic guide of Agribusiness Ukraine (n.d.)

Despite the war conditions, agrarians are trying to organise the sowing campaign as efficiently and fully as possible. There are certain trends and changes in spring crop sowing, such as a decrease in the area under maize, but an increase in the cultivation of oilseeds and some industrial crops. Alternatives must be found due to the mining of fields in the occupied territories, soaring prices for fertilisers and pesticides, and problems with the Grain

Initiative. 2022-2024 resulted in a decrease in wheat and barley acreage due to the occupation of the southeastern regions of Ukraine. However, rapeseed plantings are still at a sufficient level, which raises the chances of successful exports. Scientometric databases contain a sufficient number of papers where the researchers focus on the issues of Ukrainian agriculture. For example, F. Urak *et al.* (2024) described the impact on agricultural prices

and food security in the context of the Russian-Ukrainian war, while S. Devadoss & W. Ridley (2024) investigated the effects of the Russian invasion of Ukraine on the global wheat market. It was found that the war has complicated international activities, export-import operations, and has led to an increase in prices and a loss of welfare of Ukrainian farmers. A. Qadir *et al.* (2024) estimated the sunflower acreage in Ukraine during the full-scale Russian invasion and calculated the reduction of the acreage and the shift of cultivation from the south to the south-central regions. As a result of the full-scale invasion, there was a considerable decrease in the number of livestock. This was caused by the destruction of farms and the occupation of territories.

Despite a drop in monetary terms, exports of livestock in physical terms increased slightly. A substantial portion of the poultry population was lost due to the occupation and hostilities in the eastern and southern regions of Ukraine. Most of the poultry farms that were not affected by the hostilities increased their livestock and established new logistics routes for export. The poultry sector benefited from improved access to the EU market, which helped to avoid market overload and slowed the growth of domestic prices. At the same time, exports of dairy products even increased due to improved access to the EU market and favourable prices on the world market. The war and food security were described by I. Rudolfson *et al.* (2024), allowing for an assessment of the opportunities and losses for agribusiness in Ukraine.

The ongoing hostilities in the southeastern region of the country have led to a substantial decline in vegetable production. Farmers are forced to refocus their operations on other crops, change their activities, and enter new markets. Notably, exports declined due to the blocking of sea routes used to deliver to the Middle East and Asia. The situation in the fruit and berry market continues to be challenging, with producers facing obstacles in securing packaging materials, shortages and rising prices for fertilisers and pesticides, and problems with water and electricity supply. Despite the turbulent times since 2022, Ukraine has stayed one of the key suppliers of honey to the EU and is the second largest exporter. I. Svytnous & N. Svytnous (2023) described the development of cooperation as the basis for the formation of product supply in the honey market in Ukraine, and S.F. Razanov *et al.* (2024) described the productivity of bee colonies and biomonitoring of corbicular pollen and war-affected foraging plots of honey bees with cultivated clover.

The processing industry plays a strategically significant role in Ukraine's economy and has considerable potential for growth. With exports of agricultural raw materials blocked, the prospects for agro-processing and domestic investment by farmers in new production facilities are growing. Due to the logistical complications caused by the hostilities, the geographical structure of sugar exports has also changed, with sugar being able to be shipped to EU countries free of duties and tariff quotas. A poor harvest of raw materials and a drop in sugar production in Europe resulted in Ukraine's advantageous position on the global sugar market. Z. Mukhtar (2023) described not only changes in the sugar market in Ukraine, but also the overall impact of the Russian-Ukrainian war on food security and countries that have experienced food shock.

Thus, the changes and trends in the development of agribusiness in Ukraine under the influence of military operations allow identifying the key obstacles: rising costs of services, occupation of territories, damage and destruction, and risks of export operations. Power outages, rising prices for raw materials and fertilisers have led to a shift to alternative sources. Agrarians faced the problems of rising costs of grain processing and grain drying. Furthermore, it is impossible to conduct business in the temporarily occupied territories, while in the de-occupied territories there are threats from mine contamination of fields. Representatives of agribusiness faced the theft of agricultural products and machinery, as well as the misappropriation of industrial and domestic agricultural facilities. As a result of shelling of infrastructure and hostilities, many elevators were partially or completely destroyed. Farmers are trying to restore the operation of damaged equipment as quickly as possible by repairing it. Force majeure, blockages, and lack of stability in the operation of enterprises caused by military risks make it impossible to perform contracts for prompt delivery of agricultural products.

The full-scale invasion and ongoing military operations in Ukraine have led to certain adverse consequences, such as the loss of crops due to mined areas. Due to the inability to cultivate land and harvest, production volumes are decreasing and, accordingly, the economic situation in the country is deteriorating. The shelling and destruction led to the loss of a significant amount of agricultural machinery. The mined areas pose a threat to occupational safety and require humanitarian demining. The country's ecology has been irreparably damaged by the contamination of soil and ecosystems with chemicals. The unstable situation in Ukraine, the danger from constant shelling of the territory, elevated levels of corruption and poverty have led to an outflow of investors, which also considerably weakens the opportunities for agribusiness in Ukraine. That is why, considering the hypotheses and implications of the study of agribusiness trends, it is expedient to formulate strategic vectors for development.

In July 2023, the Ministry of Agrarian Policy and Food of Ukraine (2023) published the Strategy for the Development of the Agricultural Sector, thereby defining the vision of Ukraine's agricultural sector. The key areas of the strategy include food safety and quality, international cooperation, logistics, crop and livestock production, and the introduction of the latest technologies. Thus, four global trends in the development of agribusiness are planned to be implemented in Ukraine. The first is the growing demand for food, which is due to the steady increase in the world's population. The second trend is the issue of food security, which requires stable and coordinated work of agribusiness. The third trend is focused on the development and implementation of automation and digitalisation of agricultural processes, which helps to increase yields, reduce losses and ensure higher product quality. The fourth trend is focused on changes in climate conditions, which require innovative approaches to selecting and caring for grain varieties. Overall, for the successful development of agribusiness in Ukraine under the current conditions, it is necessary to actively introduce innovative technologies, improve the quality of agricultural products, improve supply chain management and try to maintain

stable conditions for the development of business processes. It is also necessary to improve methods of sowing, growing, storing, and supplying to ensure food security in Ukraine and reduce food shortages in the world.

M.E.B. Alam *et al.* (2023) described the crises and intense disruptions in the supply chain caused by COVID-19 and the ongoing Russian-Ukrainian war. The researchers are convinced that “Agriculture 4.0”, which combines conventional agriculture with various modern innovative technologies, can help improve food supply to markets and food security. Thus, “Agriculture 4.0” can become a prospect for the development of Ukraine’s agribusiness and ensure the sustainability of food security for the country’s economy. The key finding of the study is that automation and robotics reduce the use of manual labour, and augmented reality (AR) is designed to teach farmers innovative skills, while providing financial incentives will support farmers in developing agribusinesses. F. Sgroi (2022) described the changes that the agricultural sector underwent under the influence of the COVID-19 pandemic. What is interesting about this study is that the measures presented for agribusiness development in a pandemic can be adapted to strategic directions of development in times of war. Currently, small agricultural enterprises cannot be competitive, as they increasingly operate in a globalised

market, which leads to a gap between production and consumption. Cooperative strategies (aggregation of product supply), which underlie investment-based innovation, are the basis for the sustainability of agricultural enterprises. Considering the identified key trends of the “Strategy for the Development of the Agro-Industrial Complex”, as well as the hypotheses in Figure 7, the Hoshin Kanri model of Ukraine’s agribusiness strategy has been developed to help structure the factors, organisational design, risks, and trends in the future development of the agricultural sector. The areas presented in Figure 7 indicate that the agribusiness strategy should focus on the development of innovative technologies and the involvement of agricultural holdings in innovative activities. This will help improve key factors affecting agribusiness, avoid potential risks, and support current trends. The strategy of agribusiness in Ukraine involves the search for new methods, technologies, activities, and management solutions for production and sales. These areas will further contribute to the effective organisational design of agricultural enterprises. Effective implementation of the Hoshin Kanri Model by attracting the necessary resources will lead to increased profits and competitiveness of agricultural products both in Ukraine and on the global market, improved business processes, reduced costs, and increased customer satisfaction.

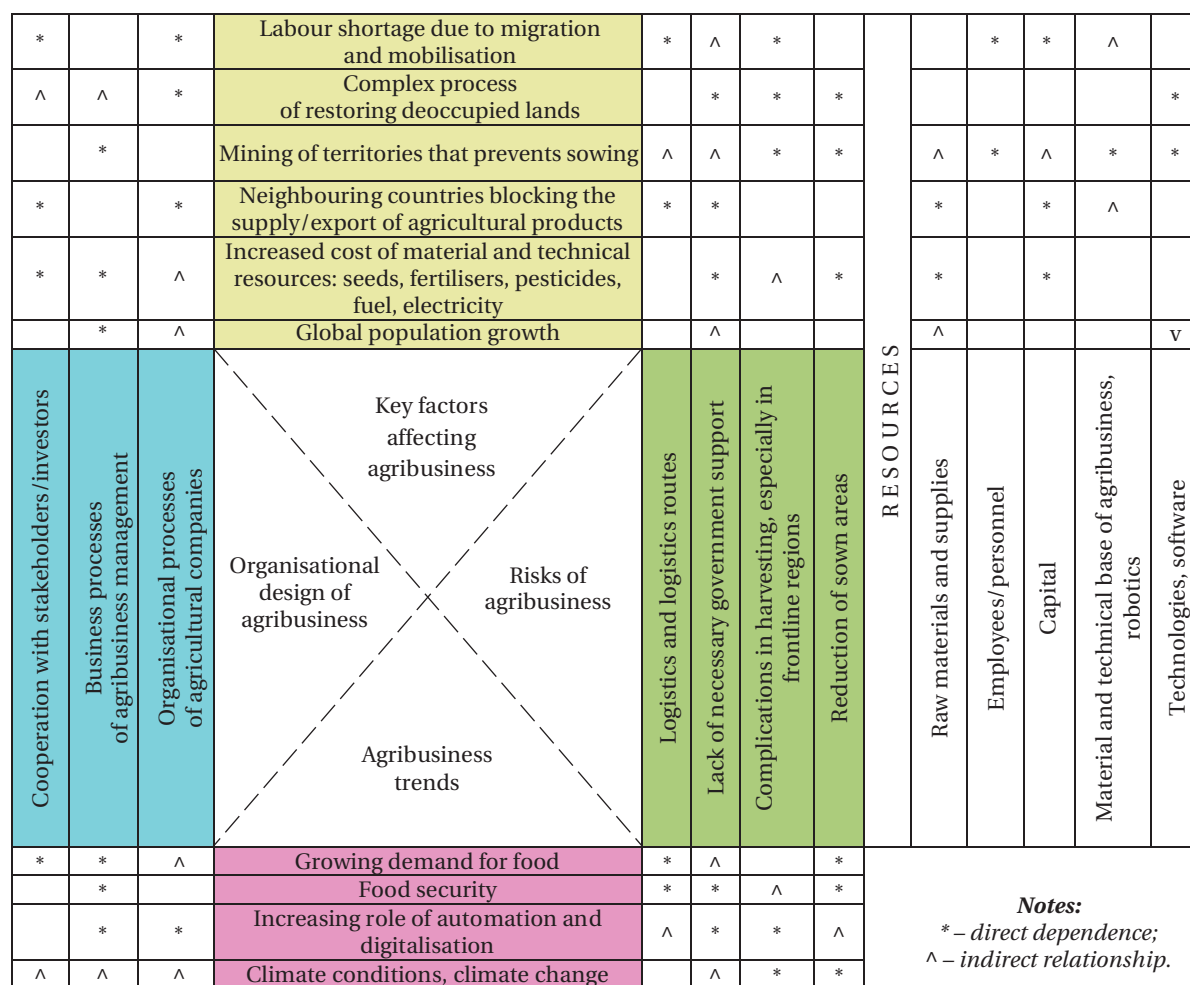


Figure 7. Hoshin Kanri’s model for Ukraine’s agribusiness strategy

Source: developed by the authors of this study

Implementation of the agribusiness strategy in Ukraine is possible even during the military operations that have been ongoing for years. The means of implementation can include grant methods for start-ups, the use of innovation vouchers in agribusiness, cooperation with scientific institutions, and rethinking the range of crops. It is critical for Ukraine to become a leader in the raw material base and establish processing plants in the country. Agribusinesses focused on further processing of grain or the implementation of joint projects to conduct several types of activities simultaneously can be much more productive.

Thus, the theoretical aspects and practical recommendations on agribusiness in Ukraine are relevant and will always be relevant in scientific research. Ukraine's geographical location allows for the implementation of the most radical innovative projects and modern technological capabilities and skills. During the war and post-war reconstruction of the country, the agribusiness strategy becomes relevant as part of the national economic development programme, which helps to create the preconditions for further implementation of the economic growth trend and sustainable development of the country's economic and food security. The implementation of the above requires a more thorough review of the issues outlined, which determines the prospects for further research on the subject matter of the study.

► Discussion

The agribusiness of Ukraine is a rather relevant area of research, as agriculture has historically been a key industry sector. Successful implementation of strategic recommendations for the development of agribusiness requires a comprehensive approach and constant analysis of market trends and consideration of consumer preferences. Furthermore, consumers come from countries on different continents, not just the domestic market. Therefore, to succeed in agribusiness, one needs to implement effective strategies. When developing and planning the implementation of such strategies, representatives of domestic agribusinesses should be guided by a clearly defined goal and target audience. Setting goals will help direct resources to the crucial aspects of the business, while identifying the target audience will help understand who the consumers are and how best to engage them in cooperation. This was the focus of the Hoshin Kanri Model for the development of Ukraine's agribusiness strategy. Overall, the development and implementation of effective strategic decisions is a crucial element of agribusiness development in Ukraine.

A bibliometric review of scientific papers using the keyword "agribusiness AND strategy" revealed a series of papers that mention the development of agribusiness. N. Reznik *et al.* (2020) considered the key aspects of innovation in the agro-industrial complex of Ukraine and the necessity of further innovative development, the principal provisions for the development of an effective innovation environment, trends in the globalisation of the international economy, and analysed the business environment of agribusiness entities. It is also relevant that, apart from numerous civilian casualties and unprecedented population displacement and migration,

the Russian-Ukrainian war will have severe environmental consequences. Climate change and ecological processes are crucial for agricultural development, which leads to deteriorating dynamics (Babenko *et al.*, 2021). Hapich & Onopriienko, 2024 considered the potential for future agricultural development of the country on the example of the region using a new conceptual strategy for water management by changing the methods of field irrigation to save energy and resources. S. Demianenko & I. Sas (2023) described ways to improve agricultural land use in the context of global warming and the consequences of Russia's military aggression. Changes in Ukraine's agribusiness are ongoing, and this is not only due to external factors, war, or global climate change. It is also significant to consider the factors of the internal environment. The existing strategies or legislative framework contain a series of shortcomings and discrepancies that adversely affect the country's economy. A. Skrypnyk *et al.* (2020) identified the benefits of an agribusiness strategy under certain conditions, namely (maximising profits or yields) based on statistical observations of yields and inputs (fertilisers, plant protection products).

The ongoing hostilities are hampering agribusiness in Ukraine. The lack of security and stability complicates farmers' access to areas that require cultivation and harvesting, with some areas still under occupation. The results of the study showed the interconnection of agribusiness with opposite types of activities. The development of information technology and the popularity of artificial intelligence are not spared from the agricultural sector. And considering that agribusiness is a broader concept, it is expedient to consider the practices of implementing digital technologies in the field of agribusiness. Z. Xue *et al.* (2024) identified the effects of digital transformation on agribusiness. It was proved that digital transformation not only expands the technological capabilities of agribusinesses, but also mitigates their financial constraints, thus facilitating the convergence of innovative resources, such as technology, talent, and capital for agribusiness and, as a result, increasing the level of innovation in agribusiness. The identified mechanisms should be factored in when formulating the agribusiness strategy in the post-war recovery of the country. Considering that agribusiness covers a wide range of tasks and involves many participants in its process, the development of a digital ecosystem will simplify and accelerate work related to the workplace; digital engineering and production; logistics management chain; digital products, services, and management systems (Osiyevskyy *et al.*, 2023).

The rapid development of digital technologies enabled M. Annosi *et al.* (2024) to identify the era of digital agriculture. The new competitive environment created by digital transformation requires strategic activation, cooperation, and cultivation of new skills and competences. At this stage, it is vital to consider digital competencies and strictly follow the rules of cybersecurity, as mentioned by Ya. Shestack *et al.* (2023). The development and proliferation of digital technologies is changing the way business sectors function, organise, and operate. In this context, the agri-food sector is no exception, undergoing a phase of radical change for organisations, devoting exponential amounts of resources to research and development and

the adoption of innovative technologies in the so-called “digital agriculture” era. During the military operations in Ukraine, there are certain restrictions on such agribusiness opportunities, but it is always expedient to consider digital technologies as a resource for agribusiness.

R.K. Bannor & K.K. Arthur (2024) identified the following main gaps that characterise the agribusiness sector, including gaps in business management and entrepreneurial skills, gaps in training, insufficient knowledge and skills of young people, insufficient skills and knowledge among women in agribusiness, and gaps in technology and innovation. This opinion is quite relevant, since during the war and mobilisation of men, many jobs were reoriented towards women. The researchers also highlighted imperfect governance and institutional reforms, social and cultural norms, poor market systems, and inadequate information flow in the agribusiness sector as gaps. The findings suggest that governments in developing countries should allocate funds for agribusiness projects and research projects that address the problems of developing countries to generate the necessary benefits in the agribusiness sector. Thus, the findings of the study showed the significance of strategic development of agribusiness in Ukraine during the war and during the country's post-war recovery. Based on the hypotheses and proposed recommendations, it is likely that the economy will improve, foreign economic activity will develop, innovations and digitalisation will be focused on, and regulatory documents will be revised.

►Conclusions

Fluctuations in demand for agricultural products, changes in land ownership, competition, and technological change are constant phenomena in the agribusiness sector. Furthermore, agribusiness in Ukraine has undergone major changes caused by the aggressor's intervention in the country. A bibliometric review of scientific papers presented in the Scopus database showed interest in agribusiness issues in various subject areas. However, a

small number of papers on agribusiness and its trends in Ukraine were found (n=129). Ensuring the sustainable development of agribusiness in Ukraine is a key issue in the context of European integration and on the path towards economic stability and competitiveness of the country. This is evidenced by the findings of the survey: Russia's military aggression against Ukraine, an imperfect legal framework, damaged infrastructure, problematic situations with sales markets, resource supply of raw materials and necessary inputs, as well as a low level of digitalisation pose significant obstacles to the development of agribusiness in the country.

The study proved the need to formulate a modern strategy for the development of agribusiness and its post-war reconstruction. For the successful implementation of the strategy, it is necessary to eliminate negative factors, ensure an adequate level of infrastructure, attract investments, develop and apply modern innovative technologies, and create favourable and safe working conditions for farmers. It is also vital to follow product quality requirements in line with international standards, develop marketing infrastructure and build own brands. That is why it is significant not only to establish sales of raw materials, but also to create opportunities for their further processing in Ukraine and develop the industrial complex. An effective strategy will not be a quick fix, but it can become a significant lever for the development of agribusiness in Ukraine, ensuring its competitiveness, economic and sustainable development. Further research perspectives lie in formulating effective measures for the development of agribusiness as a key area in the development of the country's economy.

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►Conflict of interest

None.

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► **Анотація.** В сучасних умовах війни формування стратегічних напрямів агробізнесу в Україні є невід'ємною складовою розвитку економіки у повоєнному відновленні. Метою дослідження було визначення завдань, які забезпечать можливості ліквідувати негативні тенденції спричинені війною. У роботі здійснено бібліометричний огляд наукових робіт, що присвячені питанням агробізнесу в Україні та світі. Такий аналіз дозволяє відслідкувати тенденції, виявити прогалини і невирішені напрямки для подальших досліджень, а також сформувані стратегічні напрями розвитку агросфери. Обґрунтовано зміни і тенденції агробізнесу в Україні у результаті порівняльної динаміки частки України у світовому експорті продукції агропромислового комплексу. У роботі акцентовано увагу на особливостях експорту за час дії «Зернової ініціативи», а також визначено ключові континенти експорту. Встановлено, що ключовими проблемами, які охопили агросферу, є умови нестабільної геополітичної ситуації, воєнний стан, екологічні зміни, дефіцит робочої сили та стрімкі глобалізаційні зміни. Міжнародна діяльність у агробізнесі зазнала кардинальних змін, які спричинило повномасштабне вторгнення. Саме тому розроблена стратегічна модель Hoshin Kanri розвитку агробізнесу України під час війни та повоєнному відновленні країни дозволяє побачити ключові чинники, сформувані тенденції і передбачити ризики, що впливають на агробізнес. Запропонована стратегія також враховує потребу у необхідних ресурсах для імплементації нововведень та залучення інвестицій. Це дозволить удосконалити організаційний дизайн підприємств, що орієнтовані на агробізнес. Формування стратегії розвитку агробізнесу має бути спрямовано на поширення інновацій в агробізнесі та найбільше залучення підприємств цієї сфери до інноваційної діяльності. Висновки, що отримані у межах дослідження можуть бути використані у діяльності підприємств агросфери

► **Ключові слова:** агротехнології; агропромисловий комплекс; агрохолдинги; екосистема агробізнесу; експорт; зернова ініціатива



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Marketing monitoring as a tool for assessing the competitiveness of food industry enterprises in the agro-industrial complex

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► **Abstract.** The purpose of the study was to evaluate the effectiveness of using modern marketing tools to increase the competitiveness of food industry enterprises in the agro-industrial complex in Ukraine. The research methodology employed a SWOT analysis for Myronivsky Hliboproduct (MHP) Private Joint-Stock Company and Roshen Corporation, as well as a case study of the integration of the AgriChain Land mobile application in the Astarta-Kyiv agricultural holding. The key findings of the study demonstrated that the use of digital technologies, such as CRM systems, geo-analytics and mobile applications, enhances the competitiveness of enterprises. The introduction of geo-analytics at MHP has significantly improved land and logistics management. The company mapped a third of its land bank using 150 combines, 99% of which were equipped with Field View Drive systems. At Roshen Corporation, marketing monitoring has helped to adapt the product range to changes in consumer preferences, particularly through the development of new products aimed at premium market segments, and the company holds 47% of the sweets market as of 2025. Active analysis of the competitive environment and trends enabled the company to expand its export geography and strengthen its position in international markets. Astarta-Kyiv integrated the AgriChain Land mobile application to improve land management, enabling the company to reduce the time required for management decisions by 20%. The

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use of this tool has helped optimise resources and increase operational efficiency. The study results confirmed that the use of digital technologies in marketing and management processes enables enterprises to adapt to market changes, thereby improving their competitiveness. These results can be used to develop strategies for the implementation of modern marketing tools in other agricultural enterprises

► **Keywords:** customer analysis; digital technologies; planning; geo-analytics; marketing management; innovations

► Introduction

The modern development of the agro-industrial complex in Ukraine necessitates the integration of effective marketing tools to enable food industry companies to remain competitive both domestically and internationally. The digitalisation of the economy, changing consumer preferences, and increasing global competition demand improved marketing management from companies. One of the key decision-making tools is marketing monitoring, which allows for the assessment of both internal and external factors influencing a company's development. The ability to adapt to rapid market changes is facilitated by innovative technologies such as customer relationship management systems, geo-analytics for optimising logistics processes, and online platforms for analysing consumer trends (Kovalchuk *et al.*, 2024).

In the field of assessing the competitiveness of agro-industrial enterprises, attention has been focused on improving methodological approaches. I. Naida *et al.* (2019) employed contemporary tools such as benchmarking, a competitiveness polygon, and a competitiveness profile. These methods enabled the analysis of key performance indicators for enterprises, encompassing financial, marketing, and innovation aspects. However, the development of integrated tools that account for the specific characteristics of agricultural enterprises and the modern challenges of digitalisation remained unresolved. In the current market, agricultural businesses have faced the need to adapt their management strategies to enhance their marketing potential. L. Kurbatska *et al.* (2024) explored aspects of forming the marketing potential of agricultural enterprises, emphasising the implementation of digital technologies and environmental practices, which contributed to improving company reputations and the effectiveness of marketing campaigns. The importance of collaborating with partners and adapting to global trends was highlighted. Nonetheless, the use of data analytics in the marketing activities of agricultural enterprises remained limited, impacting the effectiveness of managerial decisions and the rational allocation of resources.

In the field of assessing the competitiveness of agro-industrial enterprises, various approaches have been considered for analysing key performance indicators of production and marketing activities. N. Musayeva *et al.* (2024) conducted research employing SWOT analysis to identify the strengths, weaknesses, opportunities, and threats facing enterprises. They proposed the creation of a competitive market map, visualising producers' positions based on production volumes and growth rates. However, the development of methodologies that integrate modern digital technologies to enhance competitiveness and expand export potential remained unresolved.

In the current context, ensuring the sustainable competitiveness of the agri-food sector is a crucial task,

particularly through the implementation of innovative technologies and management strategies. Q. Guohe & Yu. Kopykovskiy (2023) analysed factors influencing the level of enterprise competitiveness and proposed strategies for adapting to market conditions. The importance of environmental standards, circular business models, and the implementation of digital platforms for monitoring and supporting agri-food supply chains was identified. Nevertheless, the integration of innovative approaches into marketing activities and mechanisms for increasing product value-added in domestic and foreign markets remains under-researched. G. Uldedaj & G. Gjeloši (2024) investigated the impact of marketing on the competitiveness of agri-food enterprises. They found that the use of internet marketing and social media contributed to increased brand recognition, consumer trust, and production expansion. However, the development of comprehensive marketing models capable of considering the specific characteristics of local producers and facilitating their integration into global markets remains a pressing issue.

In the food industry, ensuring the competitiveness of businesses is crucial through the integration of modern management strategies and innovative technologies. F. Babayev & T. Balajayeva (2023) highlighted the importance of implementing strategies to improve product quality, optimise costs, develop innovations, and understand consumer preferences. It was demonstrated that adhering to quality standards, investing in research and development, and efficient logistics management enhance a company's competitiveness. However, the development of integrated management models that can more effectively respond to changes in market conditions remains under-developed.

In the agri-food sector, it is essential to increase the effectiveness of digital marketing strategies to optimise costs and competitiveness (Rama *et al.*, 2023). N. Kanellos *et al.* (2024) investigated the impact of these strategies on business profitability, finding that using search engines reduces costs, while excessive investment in social media advertising increases them. However, there is a need to research the integration of models that consider the specific characteristics of agri-food businesses and ensure business sustainability. In the food industry, the implementation of sustainable marketing strategies to maintain competitiveness is becoming increasingly important.

M. PumaFlores & I.M. Rosa-Díaz (2024) analysed the use of such strategies in Peruvian agri-food businesses. It was determined that product certification, improved logistics capabilities, and adherence to fair trade principles significantly impact a company's reputation and competitiveness. However, the impact of innovative technologies on all stages of production and marketing of agrifood products remain insufficiently researched, requiring further study.

The aim of this study was to evaluate the marketing tools employed in the food industry to enhance the competitiveness of enterprises within the agro-industrial complex. The objectives included identifying the strengths and weaknesses of marketing activities through the application of SWOT analysis and analysing the successful implementation of marketing monitoring, including the use of CRM systems, geo-analytics for logistics, and online platforms for consumer trend analysis.

► Materials and methods

The research employed a pragmatic approach focused on analysing the practical application of marketing tools to improve the competitiveness of Ukrainian agro-industrial enterprises between 2021 and 2024. The theoretical foundation of the study was based on research that explores the core concepts and approaches to utilising digital technologies (Rana *et al.*, 2021; Ugwu & Eze, 2023; Ijomah *et al.*, 2024). Additionally, marketing tools in the agro-industrial business were examined in relevant studies (Ahmed *et al.*, 2024; MHP is an international food..., n.d.). To achieve the stated aim, a mixed-methods approach was used, including both qualitative and quantitative analysis methods. The SWOT analysis was the primary research tool, with two separate analyses conducted for Pr-JSC Myronivsky Hliboproduct (MHP) and Roshen Corporation, allowing for the identification of each company's strengths, weaknesses, opportunities, and threats in their marketing activities. Based on the results obtained, the strategic potential of each enterprise was assessed, and key areas for improvement were identified.

To analyse the implementation of the AgriChain Land mobile application in the Astarta-Kyiv agricultural holding, statistical data was collected on the amount of land returned to cultivation thanks to the use of this tool, as well as on the impact of digitalisation on managerial decisionmaking and the efficient use of land resources (The AgriChain Land system helps to..., 2021). For the evaluation of the results of marketing monitoring at Roshen Corporation, statistical data was used to confirm the effectiveness of adapting the product range to changes in consumer preferences (Akrytov, 2021). The analysis of geo-analytics at MHP also employed a case study method, focusing on the analysis of collected spatial data, which included the locations of customers, warehouses, transportation routes, and roads. The use of geo-analytical algorithms allowed for the investigation of route planning efficiency, assessing the impact of this tool on costs and product delivery times (MHP scartographed one..., 2024).

The evaluation of the AgriChain Land mobile application implementation in the Astarta-Kyiv agricultural holding was conducted through an analysis of the tool's functionality, its integration into the company's operational systems, and its impact on land resource monitoring. The research involved studying materials from the company's public sources (Astarta-Kyiv agricultural holding..., 2021; New IT-solution on land..., n.d.), which reflected the implementation process of the application, including its use for land accounting, contract management, and providing access to up-to-date land plot information. Particular emphasis was placed on studying changes in management

processes after digitalisation and their impact on business efficiency. The analysis also encompassed the relationships between technological innovations and the adaptation of management systems to changes in the external environment.

A case study method was employed to analyse the use of geo-analytics at MHP, focusing on the analysis of collected spatial data, which included the locations of customers, warehouses, transportation routes, and roads. The use of geo-analytical algorithms allowed for the investigation of route planning efficiency, assessing the impact of this tool on costs and product delivery times. This approach revealed how geo-analytics influenced the company's overall productivity, particularly in reducing costs and improving the accuracy of logistics processes. The case study method also enabled a detailed investigation of the operations of MHP, Roshen, and Astarta-Kyiv, including their marketing strategies, logistics management tools, and the implementation of digital technologies. The analysis of digital tools encompassed the evaluation of the effectiveness of CRM systems, geo-analytics, and online platforms for analysing consumer trends.

The results were interpreted considering the industry-specific characteristics of the enterprises and market conditions. By comparing data from the three companies, it was possible to identify commonalities and differences in the use of marketing tools and digital technologies. The interpretation was based on a strategic approach that included the analysis of patterns in consumer behaviour, the effectiveness of managerial decisions, and the level of adaptability of enterprises to changes in the external environment.

► Results

Marketing monitoring is a crucial tool in the food industry, enabling businesses to adapt to market changes, enhancing operational efficiency, and boosting competitiveness. In the food industry, marketing monitoring encompasses several key aspects. Firstly, consumer analysis is paramount. For food businesses, understanding consumer needs, preferences, behavioural trends, and factors influencing purchasing decisions is vital (Sardak & Dzhindzhoyan, 2018). For instance, the growing demand for organic or gluten-free products reflects current trends that businesses must address. Consumers are increasingly demanding higher quality products, eco-friendliness, transparency in the origin of raw materials, and adherence to healthy eating standards.

Secondly, competitor analysis is essential. This involves studying competitors' strategies, strengths, weaknesses, product ranges, pricing policies, advertising campaigns, and communication approaches. In the highly competitive food industry, understanding competitors' actions allows businesses to avoid repeating mistakes, leverage successful practices, and develop unique value propositions for consumers. Equally important is the evaluation of the external environment. This includes analysing economic, social, political, technological, and environmental factors that can impact businesses. For example, changes in legislation regulating food quality standards may require businesses to adapt their production processes. Conversely, technological advancements

offer new opportunities for optimising business processes and introducing marketing innovations (Pavliuk & Noda, 2020).

Modern marketing monitoring in the food industry increasingly involves the use of digital technologies. Data analytics tools, Big Data, CRM systems, geo-analytics, and market trend analysis platforms enable businesses to respond rapidly to environmental changes, forecast demand, and create personalised offers for consumers. For instance, big data analysis can uncover previously unnoticed patterns in consumer behaviour, while CRM systems facilitate more effective customer relationship management (Ijomah *et al.*, 2024). Overall, marketing monitoring provides food industry businesses with the information support necessary for making strategic and tactical decisions. This enables companies not only to maintain their competitive position but also to proactively influence the market, shaping new trends and consumer demands. Through marketing monitoring, businesses can optimise their business processes, improve resource utilisation, minimise risks, and capitalise on growth opportunities.

Marketing monitoring methods can be classified into quantitative, qualitative, and combined approaches, depending on the research objectives, data type, and collection methods. Each group has its own characteristics and methodologies, providing businesses with the ability to effectively analyse the market and make strategic decisions. Quantitative methods focus on analysing numerical data, allowing for the assessment of market size, demand forecasting, and sales analysis through surveys, statistical data, and predictive models (Rana *et al.*, 2021). Qualitative methods aim to explore consumer motivations and preferences through focus groups, in-depth interviews, and content analysis (Ugwu & Eze, 2023). Combined methods integrate both quantitative and qualitative approaches to create a comprehensive picture of the market, allowing for flexible adaptation of strategies to change (Ahmed *et al.*, 2024). Marketing monitoring empowers businesses to adapt to market changes, identify risks, and create competitive advantages. For instance, the growing demand for environmentally friendly products encourages producers to adapt their product range

by using natural raw materials and eco-friendly packaging. By analysing competitors' actions, businesses can implement innovative marketing approaches, introduce new products, or improve customer service.

Another critical aspect of marketing monitoring is resource optimisation. Through marketing monitoring, businesses can more accurately plan their expenditures, reducing spending on ineffective marketing campaigns and directing resources towards those initiatives that yield the greatest returns. This is particularly important for small and medium-sized enterprises with limited financial resources. Thus, marketing monitoring not only provides businesses with the information needed to make effective decisions but also enables them to formulate long-term strategies that foster sustainable growth. Its significance for the competitiveness of food industry businesses cannot be overstated, as it becomes the foundation for their success in today's dynamic market. MHP, a leading poultry producer in Ukraine and the company behind the well-known Nasha Ryaba brand serves as an excellent example. The company implements comprehensive marketing strategies aimed at maintaining brand recognition, satisfying consumer needs, and strengthening its position in both domestic and international markets (MHP is an international food..., n.d.). A core component of MHP's marketing activities is the systematic analysis of the market and consumer preferences. The company conducts regular research to identify new trends and adapt its products to evolving customer needs.

The development of the Nasha Ryaba brand is a top priority in MHP's marketing strategy. To strengthen brand recognition, MHP actively engages in advertising campaigns, collaborates with influencers, and participates in industry exhibitions. Additionally, the company focuses on social responsibility by implementing environmental initiatives and supporting social projects, contributing to a positive image and customer loyalty. Through a systematic marketing approach, MHP not only maintains a leading market position but also shapes trends in the Ukrainian food industry. To delve deeper into MHP's marketing activities, a SWOT analysis was conducted, as presented in Table 1.

Table 1. SWOT analysis of MHP's marketing activities

Strengths	Weaknesses
▶ High recognition and trust in the Nasha Ryaba brand ▶ Modern production facilities and innovative technologies ▶ Focus on product quality and compliance with international standards ▶ Holds approximately 47% of the Ukrainian market	▶ Dependence on the domestic market ▶ High costs of marketing campaigns ▶ Limited product range for international markets ▶ Marketing expenses amounting to approximately 600,000 UAH/year
Opportunities	Threats
▶ Expansion of international market presence ▶ Growing demand for eco-friendly products ▶ Development of digital sales channels ▶ Growth of organic products by 12.2% from 2021 to 2026	▶ Increased competition from international companies ▶ Economic instability ▶ Changes in the regulatory environment ▶ Decreased demand by 15-20% in some regions due to military actions

Source: created by the authors based on K. Akrytov (2021), MHP: All about one of the largest agricultural companies in Ukraine (2024)

The SWOT analysis highlights MHP's strengths, such as high product quality and brand recognition, which create opportunities for international expansion.

However, weaknesses like dependence on the domestic market and external threats necessitate the adaptation of the company's strategies to current challenges. Roshen,

one of the largest confectionery producers in Ukraine, has a well-established brand both domestically and internationally. Maintaining high brand recognition and strengthening its position in various market segments is a primary focus of the company's marketing activities. Roshen invests significantly in developing unique packaging designs to differentiate its products on store shelves and attract consumers. Large-scale advertising campaigns targeting diverse audiences are also crucial. The company cultivates a positive image through television commercials, social media, and involvement in cultural and social projects.

Roshen's ability to adapt its product range to changing consumer preferences is a cornerstone of its marketing strategy. The company develops new product lines to cater to the growing demand for premium, dietary, and organic products. Furthermore, Roshen successfully competes in export markets, particularly in Europe and Asia, by tailoring its strategies to the specific needs of each market. This comprehensive approach has allowed the company to remain a leader in the industry and compete with well-known global brands. To further analyse Roshen's marketing activities, a SWOT analysis was conducted, as presented in Table 2.

Table 2. SWOT analysis of Roshen Corporation's marketing activities

Strengths	Weaknesses
▶ High brand recognition in both domestic and international markets ▶ Unique packaging design and innovative marketing approach ▶ A wide product range targeting different consumer categories ▶ Market share in Ukraine of 25-27%	▶ Limited presence in new market segments, such as organic products ▶ High dependence on external markets ▶ Significant expenditure on advertising campaigns ▶ Reduced demand during the "off-season" by 15-20%
Opportunities	Threats
▶ Growing demand for dietary and organic products ▶ Expansion into new markets, particularly in Asia and Africa ▶ Use of digital platforms for brand promotion ▶ Increased exports by 50%	▶ Changes in legislation regarding food products ▶ Economic downturns in key export countries ▶ Increased competition from international companies ▶ A GDP decline could lead to a 20-25% reduction in sales

Source: created by the authors based on T. Antoniuk & O. Sharipov (2024), Roshen (n.d.)

The SWOT analysis reveals that Roshen Corporation possesses significant advantages, such as strong brand recognition and a wide product range, creating opportunities for expansion into new markets. However, threats such as economic instability and high competition necessitate further refinement of marketing strategies. Both MHP and Roshen share commonalities that contribute to their market success, but they also have distinct characteristics that shape their unique strategies. Both companies prioritise high-quality products that meet international standards, thereby fostering customer trust and ensuring consistent demand. Furthermore, they both actively invest in brand development through large-scale advertising campaigns, exhibitions, and media partnerships. Both companies also leverage modern marketing tools such as market analytics to ensure their products align with consumer needs.

Social responsibility is another shared aspect of their operations. MHP implements environmental initiatives and supports social projects, contributing to a positive brand image. Roshen, in turn, supports numerous cultural and social initiatives, which also help to increase consumer loyalty. However, there are significant differences in their strategies. MHP primarily focuses on the domestic poultry market, gradually expanding its presence in international markets, while Roshen actively operates in foreign markets, adapting its strategies to regional specificities. Product strategy also differs: MHP concentrates on a narrow product range that aligns with its specialisation, whereas Roshen offers a wide variety of confectionery products targeting different consumer segments, including the premium market. The companies' advertising approaches also vary. Roshen actively leverages cultural and social projects to promote its brand, attracting new

audiences. MHP focuses more on direct product promotion through channels that provide quick access to consumers. Thus, while both MHP and Roshen share commonalities in their marketing activities, such as a focus on quality, branding, and social responsibility, their unique approaches to market segmentation, product strategy, and advertising create distinct competitive advantages, allowing them to successfully position themselves in different market segments.

A company's competitive position in the market is shaped by its marketing strategies. For PrJSC Myronivsky Hliboproduct, a branding strategy focused on product quality has ensured a stable presence in the domestic poultry market and laid the foundation for international expansion. The trust consumers place in the Nasha Ryaba brand has allowed the company to maintain its leadership position in Ukraine, even as competition has intensified (MHP's "Nasha Ryaba" brand products received..., n.d.). Roshen Corporation, on the other hand, has become a leading confectionery producer in Ukraine and has captured a significant share of foreign markets through its diverse product range and aggressive branding. The company's use of cultural projects and unique packaging designs to market its products has cultivated a positive brand image, enhanced customer loyalty and opening up new opportunities. The strategies employed by both companies effectively influence their positioning. MHP leverages its strong brand to achieve sustainable growth domestically, while Roshen actively pursues export opportunities, underpinned by innovative marketing approaches. As a result, both companies have demonstrated successful implementation of marketing strategies to strengthen their positions and adapt to a dynamic market environment.

The effective use of marketing monitoring in the agro-industrial complex demonstrates how modern businesses can adapt to rapid market changes, increase operational efficiency, and gain a competitive edge. By leveraging technologies such as CRM systems, geo-analytics, and online platforms for consumer trend analysis, companies can make informed strategic decisions. CRM systems are a powerful tool for managing customer relationships and optimising business processes. They enable companies in the agro-industrial sector to automate interactions with end consumers, partners, and suppliers, while also improving customer service quality. Through CRM systems, businesses can increase sales effectiveness, enhance customer loyalty, and reduce costs.

The Astarta-Kyiv agricultural holding, one of the leaders in the Ukrainian agribusiness sector, serves as an excellent example of CRM implementation in the agro-industrial complex. To optimise internal business processes and manage customer relationships, the company has actively adopted CRM systems. For the creation and launch of the AgriChain Land mobile application, Astarta-Kyiv partnered with the IT company AgriChain. This strategy aims to digitalise its business processes, including land bank management and improving customer interactions. AgriChain Land is a mobile application that enables companies to access up-to-date information about land plots, fields, contractors, and contracts, even without an internet connection. This system allows company employees to quickly find and filter data, visualise the land bank map, and easily access all necessary information in the field. This significantly improves the efficiency of land management and accelerates decision-making processes (New IT-solution on land..., n.d.).

The implementation of the AgriChain Land IT solution in the Astarta-Kyiv agricultural holding has led to a significant increase in the efficiency of land resource management. The system is designed to create a structured and manageable land bank, ensuring the organisation of documentation and saving up to 20% of working time for land surveyors at all levels. In 2019, thanks to the implementation, 1,293.4 hectares of land were returned to production, and in 2020, an additional 659.84 hectares. This approach contributes to the optimisation of land use, allowing the company to make strategic decisions regarding the lease or purchase of land parcels following established boundaries and their effective use (The AgriChain Land system helps to..., 2021).

The integration of the CRM system with other corporate systems at Astarta-Kyiv allows for the maintenance of a unified database containing information about clients, products, contracts, and other business processes. This enables rapid data updates and facilitates better planning of business strategies. By leveraging CRM, the company can conduct in-depth analyses of customer needs, track order history, and create personalised offers, thereby increasing efficiency. The implementation of a CRM system at Astarta-Kyiv has streamlined sales and customer service processes. For instance, through the automation of invoicing, contact management, and order processing, the company has significantly reduced the time spent on routine tasks and enhanced employee efficiency. Consequently, customer interactions have become faster and more

accurate, leading to reduced costs and improved service quality. Moreover, the need for numerous reports, tables, and plans, along with their reconciliation and review, has been eliminated. The implementation of the new management model has resulted in an increase in order fulfilment from 50-60 to 95%. Additionally, the time required to prepare and approve documents has decreased by an average of three times, while hardware and software costs have been halved, despite a fourfold increase in the number of users and a fivefold increase in document volume (Astarta-Kyiv agricultural holding..., 2021). Another significant outcome is the improved efficiency of the land management department. The CRM system enables real-time monitoring and management of land parcels, allowing specialists to provide up-to-date information on land availability, condition, and usage history (Bovsh *et al.*, 2024). This enables the company to respond promptly to changes in land relations and optimise production processes based on accurate information.

The implementation of a CRM system has enabled Astarta-Kyiv to adopt a comprehensive approach to land bank management, integrating with other corporate systems to automate business processes. By automating data collection and processing, the CRM system facilitates more accurate planning for procurement and product supply. As a result, Astarta-Kyiv has been able to reduce transportation costs, optimise inventory, and ensure timely delivery to end consumers (Creation of a unified..., n.d.). Thanks to increased sales across all segments, Astarta's consolidated revenue for the first nine months of 2023 reached 392 million EUR, a 15% increase compared to the same period last year. This demonstrates the significant impact of the CRM system on the company's financial performance. The implementation of a CRM system at Astarta-Kyiv marks a significant milestone in the digital transformation of the agro-industrial business. This technology has enabled the company to significantly enhance operational efficiency, improve interactions with customers and partners, and adapt to market changes, ensuring long-term competitiveness and sustainable growth.

In today's competitive agro-industrial market, effective management of logistics processes is crucial to gain market access and ensure high levels of customer service (Kim *et al.*, 2025). Geo-analytics has emerged as a vital tool in achieving these objectives. Businesses are leveraging geo-analytics to collect, process, and analyse spatial data, enabling them to optimise various business processes, including logistics, and make more informed decisions. Given the perishable nature of many agricultural products, geo-analytics is particularly essential for reducing costs and improving the efficiency of logistics operations. A prime example of successful geo-analytics implementation is MHP, a leading poultry producer in Ukraine. MHP utilises geo-analytical technologies to plan its logistics processes, allowing it to not only optimise delivery routes but also effectively manage transportation costs.

MHP's geo-analytics is rooted in the collection and analysis of spatial data, including customer locations, warehouses, and points of sale, as well as data on roads, infrastructure, and available transportation. This enables the company to construct more efficient delivery routes, reducing transportation time and, consequently,

decreasing fuel costs, vehicle maintenance expenses, and driver wages. Given the perishable nature of poultry products, ensuring swift delivery is crucial for maintaining product quality and meeting customer demands. By leveraging data analysis algorithms, MHP can determine optimal delivery times and the most efficient routes for transporting products to end consumers. For instance, geo-analytics allows for the consideration of factors such as road conditions, weather, traffic congestion, and other external variables that can impact delivery times. This significantly reduces the risk of delays and unexpected costs (Chickens and BigData..., 2020). Moreover, the application of geo-analytics helps MHP to assess and optimise its company infrastructure, including warehouses and distribution centres. By identifying the most advantageous locations for warehouses and sales outlets, the company can significantly reduce transportation costs, as products are delivered directly from the nearest warehouse to the end consumer. This not only reduces transportation costs but also minimises expenses on goods handling, storage, and internal movement within the warehouse. Geo-analytics also enables the company to forecast seasonal demand fluctuations and plan its operations accordingly. For instance, during periods of high demand associated with holidays or festive seasons, the company can use geo-analytics to adapt delivery routes, avoiding delays and optimising transportation volumes.

By harnessing geo-analytics, MHP has not only reduced logistics costs but also significantly improved customer service. Swift delivery times have enabled the company to ensure timely supply and enhance customer relationships, fostering loyalty and encouraging repeat purchases. Furthermore, the company can leverage geo-analytical data to expand into new markets. By conducting precise geographic data analysis, MHP can identify promising new business regions and efficiently organise deliveries to these areas, mitigating risks and costs associated with limited market knowledge. Since the full-scale Russian invasion of Ukraine, MHP has rapidly adapted its logistics infrastructure to the new circumstances. Notably, the company significantly increased the volume of goods transported through Danube ports, compensating for losses incurred from the blockade of traditional sea routes. Additionally, the company has intensified operations at the western border, where new dry ports have emerged, facilitating the diversification of logistics routes and enhancing supply chain resilience. Overall, the application of geo-analytics in the logistics of agro-industrial enterprises is a crucial tool for improving efficiency and reducing costs. In the case of MHP, geo-analytics has not only enhanced logistics processes but also contributed to improved customer service, a key factor in maintaining competitiveness in the agro-industrial sector (Chickens and BigData..., 2020).

The implementation of geo-analytics within MHP has significantly enhanced the management of land resources and logistics processes. Notably, the company has mapped one-third of its land bank, utilising 150 combines, 99% of which were equipped with Field View Drive data transmission systems. This has allowed for the evaluation of technology effectiveness on each field parcel, enabling subsequent improvements (MHP scartographised

one..., 2024). Analysing consumer preferences and behaviours allows agro-industrial companies to adjust their strategies, particularly in response to the growing demand for organic products. Marketing monitoring also enables the assessment of competitors, identifying their strengths and weaknesses, which in turn facilitates the development of unique value propositions and the refinement of marketing strategies. Evaluating external factors such as economic, social, and political changes that can impact business operations is equally important. Modern technologies such as CRM systems, geo-analytics, and market trend analysis platforms provide businesses with the tools to swiftly adapt to market fluctuations. Consequently, marketing monitoring empowers food industry businesses to maintain a competitive edge, respond effectively to change, and thrive in dynamic market environments.

► Discussion

The increasing need for agro-industrial businesses to adapt to dynamic market changes and intensified global competition underscores the importance of enhancing their competitiveness. In this context, digital technologies and innovative approaches play a crucial role in creating competitive advantages. The findings of this research highlight the effectiveness of marketing monitoring as a tool for enabling agro-industrial enterprises to adapt to evolving consumer preferences and market trends. The utilisation of technologies such as CRM systems, geo-analytics, and online platforms empowers businesses to respond promptly to changes, optimise business processes, and enhance competitiveness. These results underscore the significance of innovative tools for improving market strategy management. In comparison, the research conducted by I. Kryukova *et al.* (2024) emphasises the use of controlling as a tool for optimising internal processes and strategic management through the analysis of costs and financial indicators. While both studies aim to improve management efficiency in the agro-industrial sector, the primary difference lies in their focus: this research highlights the role of market-oriented tools and digital technologies, whereas study by I. Kryukova *et al.* study concentrates on internal processes and financial aspects.

A comparison with the research conducted by K.M. Łukiewska (2024), which focused on strategic resource management for achieving international competitiveness, reveals distinct approaches. K.M. Łukiewska employed factor analysis to examine the impact of resources on the competitiveness of Polish enterprises, whereas this study centred on marketing tools for analysing consumer trends and adapting to local market conditions. Consequently, the findings of this research highlight the importance of utilising digital technologies and market-oriented tools to ensure business adaptability, while the research of other authors suggests alternative approaches focused on internal resource management and strategic planning. Both approaches complement each other, providing opportunities for a comprehensive approach to managing the competitiveness of agro-industrial enterprises. In the research conducted by F.V. Guliyev (2022), the primary focus lies on marketing audits as a method for evaluating and improving the effectiveness of marketing strategies. The authors emphasise the importance of regular reviews

of marketing processes, enabling the identification of weaknesses and the subsequent adjustment of enterprise strategies, thereby enhancing competitiveness. This approach emphasises the systematic review and improvement of marketing activities, focusing on optimisation and effectiveness at all stages.

The research conducted by I.C. Baierle *et al.* (2022) and this study present distinct approaches to enhancing the competitiveness of agro-industrial enterprises. While both aim to improve business performance, they focus on different aspects. I.C. Baierle *et al.* emphasise the integration of digital technologies, particularly CRM systems, to improve business processes. Their research highlights the comprehensive application of digital solutions to enhance both managerial and marketing functions within enterprises. In contrast, this study focuses on the utilisation of various contemporary methods for market monitoring and adapting to evolving consumer preferences. This research highlights the importance of timely market response and strategic adjustments to enhance competitiveness. The primary difference between the two studies lies in their emphasis. I.C. Baierle *et al.* underscore the holistic implementation of digital technologies across all aspects of business operations, while this study concentrates on specific tools for market analysis and monitoring to adapt strategies according to changing consumer behaviour.

In the study by Q. Muftaydinov (2023), the results demonstrate an alternative approach centred on traditional methods, such as improving production processes, diversifying product ranges, and strategic planning. The use of SWOT analysis in Q. Muftaydinov's article aims to evaluate internal resources and the ability of enterprises to adapt to external environmental changes. However, compared to digital technologies that enable businesses to respond rapidly to market challenges, traditional methods may appear less flexible, although they remain effective for strategic development. The results of this study also differ from the research of K.M. Priya & S. Alur (2023), which focuses on improving production processes and product diversification strategies. Unlike the author's approach, which centres on the integration of digital technologies into marketing strategies, the findings of K.M. Priya & S. Alur emphasise the importance of analysing traditional business processes to form effective solutions in changing market conditions. While both approaches demonstrate value in enhancing competitiveness, the application of digital technologies in current research allows for more flexible adaptation to evolving consumer preferences and rapid adjustments to market strategies. Thus, the analysis shows that while traditional methods remain useful for long-term planning and strategic management, the integration of modern technologies provides an additional advantage in the face of rapid market changes, facilitating swift adaptation and increased competitiveness.

Both this study and the article of H. Ding *et al.* (2023) delve into the significance of technology in advancing the food industry, particularly in terms of product safety and quality. While both studies focus on innovations that enhance production efficiency through the application of artificial intelligence and big data, they differ in their emphasis on specific technologies and practices. The current study places a strong emphasis on the use of tools for

analysing consumer trends. These technologies facilitate the collection of crucial data to improve marketing strategies and decision-making within agro-industrial companies. In contrast, H. Ding *et al.* highlight the role of big data and artificial intelligence in optimising production processes, enhancing product safety, and ensuring quality. While this study primarily focuses on developing market monitoring strategies through the use of cutting-edge technologies, H. Ding *et al.* concentrate on the technical aspects of implementing AI and big data to improve production efficiency and product safety. A significant emphasis in their research is the integration of AI with big data for more accurate demand forecasting, process optimisation, and cost reduction through intelligent management systems.

The present research and the study of Yu. Perehuda & N. Korobova (2023) share a common focus on enhancing the competitiveness of the agro-industrial sector, specifically in animal husbandry, through the application of digital marketing tools. However, the approaches to achieving these goals differ significantly, particularly in terms of the specific industry niches explored, such as snail farming and organic aquaculture, as studied by Yu. Perehuda & N. Korobova. The findings of Yu. Perehuda & N. Korobova emphasise the importance of planning and implementing digital marketing for livestock farms, especially in the context of economic volatility. Their research highlights the need for a deep analysis of production costs, pricing, and contractual terms. A key aspect is the use of a phased approach to implementing digital tools, including defining a targeted product mix, setting target prices, and establishing a sales calendar to ensure product competitiveness (Palamarchuk & Korkach, 2023).

The conducted study examined the effectiveness of implementing integrated digital tools to help agro-industrial businesses adapt to market changes. The utilisation of modern technologies allows not only for the analysis of market trends and demand forecasting but also for the optimisation of operational processes such as supply chain management and logistics (Shtal *et al.*, 2023). This creates a foundation for rapid responses to evolving consumer preferences and provides businesses with a competitive edge. The findings of this research highlight the advantages of this approach compared to the article of O. Ievseitseva & O. Mihalatii (2024), which focuses on a broader range of tools, including product innovations and personalised marketing strategies. Unlike the focus on specific digital tools in this study, O. Ievseitseva & O. Mihalatii's approach concentrates on developing strategies for adaptation to new market conditions through the broad integration of innovations into marketing.

The analysis also highlights significant differences between this study and the findings of Sufyan *et al.* (2024). In their research, Sufyan *et al.* focus on product innovations, particularly the creation of healthy, organic, and gluten-free products that align with current consumer trends. While such approaches foster customer loyalty and expand market share, they are less focused on the utilisation of digital technologies. In contrast, this study demonstrates the effectiveness of employing technology to optimise marketing strategies and adapt to market changes swiftly. Thus, the discussion of different approaches

underscores the importance of integrating both technological and product innovations.

Similarly, while both this study and the research of E. Rahmadani & E. Elinur (2024) focus on digital strategies to enhance the competitiveness of the agricultural sector, there are distinct approaches. E. Rahmadani & E. Elinur emphasise the use of social media, e-commerce, and SEO to expand markets and interact with end consumers. They also address challenges such as infrastructure limitations and digital literacy. This study, however, places more emphasis on the implementation of CRM systems, geo-analytics, and online platforms for analysing consumer trends, particularly for optimising logistics and production processes.

The research by R. Abiri *et al.* (2023) focuses on digital agriculture technologies such as the Internet of Things (IoT), artificial intelligence (AI), automation, and sensors, and their application in enhancing agricultural processes like crop health monitoring, soil quality control, and cost reduction. A key difference between this research and the current study lies in the emphasis. While this study concentrates on the commercial aspects of using digital tools for monitoring and managing marketing processes within the agro-industrial complex, R. Abiri *et al.* focus on using these technologies to improve agricultural productivity through automation and integration with high-precision monitoring systems.

N. Khomiuk *et al.* (2022) emphasise the importance of marketing tools in enhancing the competitiveness of agro-industrial enterprises in Ukraine. Their research highlights the role of agromarketing as a fundamental tool for driving economic growth in the agricultural sector by aligning businesses with market demands and consumer needs. The primary focus is on marketing communication strategies, market research, competitor analysis, and catering to the growing demand for agricultural products. Notably, the research emphasises the need for integrating marketing tools to optimise business operations, enabling enterprises to successfully adapt to changing market conditions and economic situations. The current study, in contrast, emphasises the use of modern digital tools to significantly improve the efficiency and accuracy of marketing management processes.

Both this study and the research of O. Dovgal *et al.* (2017) share a common focus on enhancing the competitiveness of agro-industrial enterprises, but they differ in their approaches and methodologies. While both acknowledge the significance of competitive advantages in the agricultural sector, they analyse these aspects from distinct perspectives. This study emphasises the application of digital technologies, such as CRM systems, geo-analytics, and online platforms, to enhance competitiveness in the agro-industrial sector. It focuses on innovative approaches and the use of modern market monitoring tools, enabling businesses to respond swiftly to changing consumer trends and improve efficiency.

In contrast, the research by Yu. Okhota *et al.* (2024) presents a conceptual multi-component model of an innovation mechanism for enhancing the competitiveness of agro-industrial enterprises. The authors highlight the need to implement innovative technologies and develop energy potential to increase the efficiency of agricultural

enterprises, especially in the context of globalisation and competition. They propose the creation of an innovation management system that would allow enterprises to adapt to changes and ensure sustainable development through the optimal utilisation of resources and energy. The study confirmed the importance of integrating modern technologies to improve the competitiveness of agribusinesses. A comparison of the different approaches shows that innovative tools, such as marketing monitoring and CRM systems, facilitate quick adaptation to market changes, thereby increasing management effectiveness.

► Conclusions

The present study demonstrated the high effectiveness of using modern marketing tools in enhancing the competitiveness of food industry enterprises within the agribusiness sector. Based on an analysis of the activities of these enterprises, it was established that the implementation of marketing monitoring is an integral part of their strategic development. In particular, the integration of technologies such as CRM systems, geospatial analytics, and online platforms provides a significant competitive advantage, fostering flexibility in adapting to changing market conditions. An analysis of the activities of PrJSC Myronivsky Hliboproduct, the Roshen Corporation, and Astarta-Kyiv revealed the key aspects that define their competitiveness.

MHP actively employs geo-analytics to optimise logistics processes. This enables a reduction in transportation costs, shorter delivery times, and ensures the preservation of product quality. The use of CRM systems enhances customer relationship management, increases customer loyalty, and facilitates the creation of personalised offers. These measures have helped MHP maintain its leadership position in the domestic market and actively develop export channels. The implementation of geo-analytics at MHP significantly improved land resource management and logistics. The company mapped a third of its land bank using 150 combine harvesters, 99% of which were equipped with Field View Drive systems.

The Roshen Corporation focuses on expanding its product range and creating innovative product lines adapted to changing consumer preferences, such as premium and organic products. The high level of brand recognition is ensured through active advertising, participation in social and cultural projects, as well as an innovative approach to packaging design. This has strengthened Roshen's position in the international market and expanded its market share in new regions, with the company now holding 47% of the market share. The integration of market research into the product development process has enabled the company to anticipate market trends and introduce new products in a timely manner, providing a long-term competitive advantage.

Astarta-Kyiv has demonstrated the successful integration of the AgriChain Land mobile app, which helps optimise land resource management. This approach facilitates access to up-to-date information on land plots and contributes to cost reduction, which, in turn, positively impacts the overall efficiency of the company's operations. The use of analytical tools to monitor market conditions has enabled Astarta to adjust its strategy in response to changes in demand, regulatory conditions, and

environmental challenges. Additionally, it has reduced land bank management costs by 20% of land surveyors' working time. In 2019, thanks to the implementation of this solution, 1,293.4 hectares of land were returned to production, and in 2020, a further 659.84 hectares were brought back into use, improving land efficiency.

The application of marketing monitoring, including competitor analysis, consumer preferences, and external environment analysis, enables agro-industrial enterprises to develop adaptive strategies. The utilisation of modern digital technologies ensures flexibility and precision in decision-making, fostering competitiveness even in challenging market conditions. Special attention should be paid to combining marketing tools with operational decisions, enabling the creation of integrated business

models for long-term development. Moreover, it is crucial to note that enterprises combining market research with technological innovations demonstrate higher adaptability and the ability to respond more effectively to external challenges. Future research should focus on analysing the effectiveness of integrating the latest digital technologies into the marketing strategies of small agro-industrial enterprises and assessing their impact on economic sustainability.

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► Conflict of interest

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Маркетинговий моніторинг як інструмент оцінки конкурентоспроможності підприємств харчової промисловості в агропромисловому комплексі

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► **Анотація.** Метою дослідження було оцінити ефективність використання сучасних маркетингових інструментів для підвищення конкурентоспроможності підприємств харчової промисловості в агропромисловому комплексі України. Методологія дослідження включала SWOT-аналіз для приватного акціонерного товариства «Миронівський хлібопродукт» (МХП) та корпорації «Roshen», а також кейс-стаді інтеграції мобільного додатку AgriChain Land в агрохолдингу «Астарта-Київ». Ключові висновки дослідження продемонстрували, що використання цифрових технологій, таких як CRM-системи, геоаналітика та мобільні додатки, підвищує конкурентоспроможність підприємств. Впровадження геоаналітики в МХП значно покращило управління земельними ресурсами та логістикою. Компанія нанесла на карту третину свого земельного банку, використовуючи 150 комбайнів, 99 % з яких були оснащені системами Field View Drive. У корпорації «Roshen» маркетинговий моніторинг допоміг адаптувати асортимент продукції до змін споживчих уподобань, зокрема, шляхом розробки нових продуктів, спрямованих на преміум-сегменти ринку, і станом на 2025 р. компанія займає 47 % ринку солодошів. Активний аналіз конкурентного середовища та тенденцій дозволив компанії розширити географію експорту та зміцнити свої позиції на міжнародних ринках. «Астарта-Київ» інтегрувала мобільний додаток AgriChain Land для покращення управління земельними ресурсами, що дозволило компанії скоротити час, необхідний для прийняття управлінських рішень, на 20 %. Використання цього інструменту допомогло оптимізувати ресурси та підвищити операційну ефективність. Результати дослідження підтвердили, що використання цифрових технологій у маркетингових та управлінських процесах дозволяє підприємствам адаптуватися до ринкових змін, тим самим підвищуючи свою конкурентоспроможність. Ці результати можуть бути використані для розробки стратегій впровадження сучасних маркетингових інструментів на інших сільськогосподарських підприємствах

► **Ключові слова:** аналіз споживачів; цифрові технології; планування; геоаналітика; управління маркетинговою діяльністю; інновації



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The impact of the agricultural sector on the sustainable development of rural territorial communities

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► **Abstract.** The agricultural sector is one of the key components in achieving a higher level of sustainable development goals in Ukraine. Consequently, examining the interaction between these two aspects, including at the regional level, remains highly relevant. This study aimed to assess the impact of Ukraine's agricultural sector on the country's ability to achieve sustainable development at the regional level. The research focused on the agricultural sector of Mykolaiv region. Based on available statistical data for the region and Ukraine as a whole, the study summarised trends indicating a decline in livestock production and identified the underlying causes of this trend in the country. In particular, it was noted that contributing factors include climatic conditions (such as droughts and water shortages, exacerbated by the destruction of the Kakhovka Hydroelectric Power Plant), technological constraints, outdated equipment, and insufficient breeding programmes. It was shown that while there has been an overall increase in crop productivity across the country, the trend has been inconsistent: productivity initially rose but began to decline following the full-scale invasion in 2022. Additionally, examples of corporate social responsibility initiatives aimed at developing rural territorial communities were presented. The complex interplay of economic, environmental, and technological factors shaping the current development characteristics of the Mykolaiv region was also highlighted. The findings of this study may be utilised by national and local authorities in formulating strategies for achieving sustainable development goals, as well as by agricultural enterprises in developing their own long-term growth strategies

► **Keywords:** local economic development; microeconomics; corporate social responsibility; local authorities; standard of living

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► Introduction

Agriculture is a cornerstone of achieving sustainable development goals, particularly in countries where the agricultural sector is a leading driver of economic growth. Given this, the interrelationship between agriculture and sustainable development is significant in Ukraine. Special attention should be given to the experiences of communities, especially in the Mykolaiv region, which has suffered from prolonged military actions by Russia.

L.M. Zomchak (2023) assessed the potential for achieving better results in terms of sustainable development goals in Ukraine. The researcher constructed a model using a three-component approach – economic, social, and environmental. The economic component was represented by GDP, influenced by wages, turnover, exports, and inflation; the social component was represented by per capita income and employment levels; and the environmental component encompassed expenditures related to environmental protection. Based on the model, it was concluded that household incomes are growing faster than GDP, although the latter correlates with increases in both household incomes and environmental expenditures. The relationship between these variables indicates a complex interplay among these components of sustainable development. Furthermore, significant attention was paid to the negative impact of Russia's full-scale invasion on Ukraine's sustainable development. The conceptual foundations for sustainable development in Ukraine were examined in the study of T. Kharchenko (2021), which emphasised the importance of considering the agricultural sector and rural areas as a complex system requiring the application of the sustainable development concept for its formation. Moreover, the study highlighted the need to utilise mechanisms such as government regulation and economic, social, environmental, and managerial spheres of influence.

Research on the experience of rural areas through the stimulation of agritourism was conducted by Ye. Romanenko *et al.* (2020). In their view, rural development depends on the rural population, labour productivity, and government support for innovation. The tourism industry significantly contributes to the development of rural areas, unlike the agricultural sector, which is playing an increasingly smaller role in both national and regional economies. Therefore, policies focused on addressing environmental issues, increasing the competitiveness of European tourism, boosting demand for services, improving tourism products, and developing technologies in the sector are crucial. The potential for developing agricultural tourism was also described by M. Dziamulych *et al.* (2021). They highlighted the potential for agritourism development in Ukraine to improve the standard of living both nationally and locally, as well as to preserve cultural heritage. With its unique natural and cultural resources, the western region of Ukraine is particularly suited for agritourism development (Roman *et al.*, 2024). While numerous scholars associate the potential for regional development in Ukraine with agritourism, it is crucial to recognise that its formation and development are only feasible after the war has ended.

I. Petrunenko *et al.* (2021) noted the importance of overcoming current threats to the development of the agro-industrial complex in Ukraine. They suggested that improved economic security could be achieved through the agricultural sector by utilising unused farmland.

Meanwhile, N. Martynovych *et al.* (2023) explored the possibilities of rebuilding Ukraine's territory while considering the need for sustainable development. These authors concluded that the country required a new economic development model in the post-war period, primarily based on exporting agricultural raw materials. The researchers also noted that sustainable development has become a central concept for Ukraine's post-war development and proposed a set of indicators that can be used to develop a methodology for adhering to sustainable development principles in the country.

Thus, contemporary economic literature places significant emphasis on research into the interplay between the agricultural sector and the achievement of sustainable development goals. However, relatively little attention has been paid to the livestock sector compared to crop production. Nevertheless, at the regional level, assessing the impact of agriculture on regional sustainable development remains a relevant topic. Given this, this study aimed to evaluate the influence of agricultural sector development on achieving sustainable development goals in regions.

► Materials and methods

The study utilised specific statistical data to comprehensively assess the role of the agricultural sector in Ukraine's economic development. One of the primary sources of information was the State Statistics Service of Ukraine (n.d.). This resource provides access to detailed indicators, enabling analysis of trends in various sectors, particularly the agricultural sector, which is especially valuable for economic research. However, the bulk of the data for this study was sourced from the Main Department of Statistics in Mykolaiv Region (n.d.). Some data, particularly in the tables comparing the situation in Ukraine as a whole and in the Mykolaiv region, was only used up to 2022 (inclusive). This limitation is due to the unavailability of more recent data for this period. Furthermore, it was not possible to analyse data for individual united territorial communities, as statistical information in the public domain for these communities is absent. This source provided specific information, including the number of farm animals slaughtered, milk production volumes, the number of cattle and pigs, and crop yields for grains, legumes, and sunflowers. Additionally, the Mykolaiv Regional Statistics Office provided data on the GDP of agriculture, allowing for a deeper understanding of the dynamics of agricultural productivity in the region. This data was used to assess the role of the agricultural sector at the regional level and to compare it with national indicators. Information from various other sources was also utilised, including the European Commission, National Institute of Strategic Studies (2023), the Zabolotiv Territorial Community website (Areas of agricultural..., 2024), and others.

A mixed-methods approach, incorporating both quantitative and qualitative methods, was employed in this research to comprehensively assess the impact of agriculture on Ukraine's economy. Specifically, the study focused on Ukraine as the primary case study, while also including an analysis of international sustainable development practices, particularly those of the EU and the USA. This comparative framework helped to identify opportunities for integrating international sustainable

practices, such as animal welfare, environmental protection, and greenhouse gas emissions reduction, into the Ukrainian context. This allowed for an evaluation of the effectiveness of relevant international approaches and the drawing of conclusions regarding their potential adaptation in Ukraine to improve outcomes in the agricultural sector. A comparative method was used to assess the situation in Ukraine, the USA, and the EU, highlighting similarities and differences across these countries. Additionally, tabular and graphical methods were employed to visualise trends and structural changes.

The study examined case studies of cooperative initiatives and educational projects in Ukrainian agricultural enterprises to demonstrate the sector's role in social and economic resilience. Statistical tools were employed for quantitative analysis to identify correlations between agricultural development indicators in Mykolaiv and Ukraine as a whole. A correlation was considered significant if the coefficient exceeded ± 0.6 . This indicated a strong relationship between the indicators, while lower values suggested a lack of significant correlation between the variables. This approach allowed for an assessment of the extent to which trends in agriculture at the regional level correlate with national indicators and how the Mykolaiv region aligns with or deviates from the overall dynamics of agricultural development in Ukraine. In cases of low correlation, specific factors unique to the Mykolaiv region were considered, as these factors would likely have influenced changes in sectoral development at the local level due to its differences from the national average.

► Results

The agricultural sector plays a pivotal role in economic development, particularly in countries where farming is the primary source of income and employment. It is a fundamental source of food, essential for a nation's population, as self-sufficiency in food reduces reliance on imports, ensuring economic stability. Moreover, in many countries, the agricultural sector is a major employer, providing jobs for a significant portion of the population, especially in rural areas, thus reducing unemployment and improving living standards. In Ukraine, the sector constitutes a substantial portion of GDP and exports (a primary source of foreign exchange earnings, positively impacting the balance of payments and strengthening the national currency). The agricultural sector stimulates the development of other economic sectors such as agricultural machinery, chemical industries (fertilisers, pesticides), transport services, and the food processing industry. Its growth enhances living conditions in rural areas, including access to education, healthcare, and infrastructure, and ensures the sustainability of ecosystems (Lazareva, 2022).

Sustainable development is also a critical component of any country's development (Laurett et al., 2021), including Ukraine. It encompasses economic, social, and environmental aspects that together contribute to improving the quality of life for the population and ensuring

long-term well-being. Sustainable development also fosters economic growth but in a way that does not deplete natural resources and ensures lasting economic stability (Carmela Annosi et al., 2020; Patkós, 2020; Chopra et al., 2022). The implementation of sustainable technologies and practices can create new jobs in green energy, eco-friendly construction, and organic agriculture (Lehtonen et al., 2021). The concept positively influences the development of technologies that increase resource efficiency and reduce negative environmental impacts. Socially, sustainable development can improve living conditions by providing access to clean water, sanitation, healthcare, and quality education. It promotes social justice and helps to reduce the gap between the rich and the poor (Rounaghi et al., 2020). Furthermore, sustainable development encourages citizen participation in decision-making that affects their lives and environment, thereby strengthening democracy and social cohesion. Environmentally, sustainable development ensures the rational use and conservation of natural resources, such as water, forests, and biodiversity. The implementation of clean technologies helps reduce air, water, and soil pollution (Qiu et al., 2021). Moreover, sustainable development contributes to reducing greenhouse gas emissions and adapting to climate change, which is crucial for preventing environmental disasters. Achieving the goals of sustainable development has become an international development strategy for many countries (Lajoie-O'Malley et al., 2020; Hrustek, 2020). Researchers have noted that the concept also fosters international cooperation: countries that actively implement sustainable development can strengthen their position on the international stage and attract more investment.

Therefore, agriculture plays a pivotal role in achieving sustainable development goals, contributing to economic growth, environmental conservation, and social well-being (Tiurina et al., 2021; Dovgal et al., 2024). It is a primary source of income and employment for a significant portion of the population, especially in rural areas, and increasing productivity and incomes in this sector can help reduce poverty and inequality. Moreover, supporting small-scale farmers and developing agribusinesses fosters economic growth at both the local and national levels. Additionally, the development of sustainable agriculture leads to increased food production, helping to ensure food security, while improving the quality and diversity of food products contributes to better nutrition and health. The use of environmentally friendly farming practices helps reduce negative environmental impacts, including greenhouse gas emissions, and protects water resources and biodiversity. Furthermore, the development of this sector supports social stability by creating jobs and reducing migration from rural to urban areas (Bexolli et al., 2023). Due to a lack of corresponding data, it is not feasible to analyse trends in more detail for individual united territorial communities. However, such an analysis can be conducted for the region as a whole. The selected data for the years from 2017 onwards are presented in Table 1.

Table 1. Selected data characterising agriculture in the Mykolaiv region from 2017 to 2023

Year	2017	2018	2019	2020	2021	2022	2023
Area of cultivated agricultural crops (thousands of ha)	1,560.1	1,564.8	1,572.3	1,564.9	1,607.1	1,300.6	1,231
Area harvested for cereal crops (thousands of ha)	874.9	867.8	890.2	880.7	950.5	705.2	617.7

Table 1, Continued

Year	2017	2018	2019	2020	2021	2022	2023
Cereal crop production volume (thousands of centners)	26,746.4	26,734.2	31,379	23,620.6	39,255.4	21,336.4	24,131.2
Cereal crop yield (centners per ha)	30.6	30.8	35.3	26.8	41.3	30.3	39.1
Area harvested for fodder crops (thousands of ha)	3	2.5	2.3	2.2	2.2	1.4	0.9
Fodder crop production volume (thousands of centners)	492.3	390.8	417.1	338.1	441.1	255.9	156.4
Fodder crop yield (centners per ha)	161.9	155.5	182.5	156.4	200.2	179.8	178.8

Source: compiled by the authors based on data from the State Statistics Service of Ukraine (n.d.) and the Main Department of Statistics in Mykolaiv Region (n.d.)

Analysing agricultural production data from 2017 to 2023 reveals several key trends. Sown areas for harvested crops exhibited stability with a slight increase from 2017 to 2019, but in 2021, the area grew significantly, followed by a decline to 1,231 thousand ha in 2023, likely due to the onset of Russia's full-scale invasion of Ukraine and the temporary occupation of certain territories. Grain crop production fluctuated during the study period, also

declining after 2022 with a slight recovery in 2023, suggesting a positive trend towards increased production efficiency. Harvested areas of fodder crops have been steadily decreasing from 2017 to 2023 – from 3 to 0.9 thousand ha. Consequently, fodder crop production has also fallen, especially after 2019, indicating a potential reduction in feed production for livestock. A more detailed analysis of the livestock sector is presented in Tables 2 and 3.

Table 2. Data on live weight sold for slaughter, milk production, eggs from poultry, and wool production in Ukraine and Mykolaiv region from 2013 to 2022

Ukraine					
Year	2013	2014	2015	2016	2017
Live weight sold for slaughter (thousand tonnes)	3,378.8	3,323.5	3,279.9	3,271.6	3,265.9
Milk production (gross yield) (thousand tonnes)	11,490	11,132.8	10,615.1	10,381.5	10,279.6
Eggs from poultry (million pieces)	19,603.7	19,587.3	16,781.2	15,100.4	15,525.9
Wool production (gross shearing) (tonnes)	3,525	2,602	2,270	2,072	1,971
Year	2018	2019	2020	2021	2022
Live weight sold for slaughter (thousand tonnes)	3,317.6	3,492.7	3,462.3	3,391.2	3,059.1
Milk production (gross yield) (thousand tonnes)	10,064	9,697	9,263.6	8,713.9	7,767.7
Eggs from poultry (million pieces)	16,132	16,676.6	16,167.2	14,071.3	11,921.8
Wool production (gross shearing) (tonnes)	1,908	1,734	1,574	1,497	1,237
Mykolaiv region					
Year	2013	2014	2015	2016	2017
Live weight sold for slaughter (thousand tonnes)	49.6	57.7	52	49.8	48.1
Milk production (gross yield) (thousand tonnes)	370.7	369.3	343.8	341.6	342.2
Eggs from poultry (million pieces)	299.6	500	284.1	271.5	252.7
Wool production (gross shearing) (tonnes)	101	124	123	124	132
Year	2018	2019	2020	2021	2022
Live weight sold for slaughter (thousand tonnes)	56.4	50.9	40.3	40.3	33.8
Milk production (gross yield) (thousand tonnes)	324.6	299	278.5	245.7	197.3
Eggs from poultry (million pieces)	240.1	275.4	201.6	156.9	136.2
Wool production (gross shearing) (tonnes)	146	113	98	100	75

Source: compiled by the authors based on data from the State Statistics Service of Ukraine (n.d.) and the Main Department of Statistics in Mykolaiv Region (n.d.)

Table 3. Data on the number of cattle (including cows), pigs, and poultry in Ukraine and Mykolaiv region from 2013 to 2022, in thousand heads

Ukraine					
Years	2013	2014	2015	2016	2017
Cattle	4,645.9	4,534	3,838.5	3,983.9	3,682.3
Cows	2,554.3	2,508.8	2,174.1	2,276.2	2,108.9
Pigs	7,576.7	7,922.2	7,042.7	7,313	6,669.1
Poultry	214,070.6	230,204.7	198,864.4	206,633.6	201,668
Years	2018	2019	2020	2021	2022
Cattle	3,573.7	3,332.9	3,117.7	2,874	2,662.8
Cows	2,040.5	1,919.4	1,806.5	1,673	1,555.3
Pigs	6,108.6	6,025.3	5,730.4	5,876.2	5,611.9

Table 3, Continued

Ukraine					
Years	2018	2019	2020	2021	2022
Poultry	204,751.5	211,654.4	220,463.2	200,651.9	202,243.1
Mykolaiv region					
Years	2018	2019	2020	2021	2022
Cattle	150.3	154.5	141.9	139.3	140.4
Cows	89.8	90.1	80.1	81.7	77.8
Pigs	139.6	147.1	113	129.5	99.9
Poultry	3,723.9	4,248.3	2,666.6	2,915.9	2,708.9
Years	2018	2019	2020	2021	2022
Cattle	145.1	98.5	86.9	74	66.6
Cows	74.6	60.8	54	47.4	43
Pigs	90.5	83.1	77.6	72.6	67.6
Poultry	2,723.6	2,554.2	2,453.2	1,957.1	1,994.7

Source: compiled by the authors based on data from the State Statistics Service of Ukraine (n.d.) and the Main Department of Statistics in Mykolaiv Region (n.d.)

As Table 3 shows, the trend in agricultural production in Ukraine and the Mykolaiv region from 2013 to 2022 has been declining in key categories: meat, milk, eggs, wool, and live weight of animals sold for slaughter. Data on the number of cattle, cows, pigs, and poultry in Ukraine and the Mykolaiv region from 2013 to 2022 indicates a general decline in livestock numbers, particularly cattle and pigs, suggesting declining profitability and high costs that are limiting growth in the agricultural sector. By identifying correlations between the corresponding indicators characterising trends in the Mykolaiv region and Ukraine, it is possible to assess the reasons for these trends. Given that the correlation coefficients are high (above 0.75) for all indicators except live weight and wool production, it can be inferred that the decline in indicators is primarily linked to overall economic trends, namely the onset of the war with Russia in 2014 and the full-scale invasion of Russia in 2022. The more rapid decline in the Mykolaiv region is largely due to its proximity to the war zone and the temporary occupation in 2022.

Livestock productivity in Ukraine is influenced by numerous factors that interact in complex ways. One such factor is climate. Droughts and water scarcity, particularly in southern regions, create challenges for growing fodder crops, leading to feed shortages and directly impacting livestock productivity. The destruction of the Kakhovka Hydroelectric Power Plant has exacerbated this issue, as farmers in southern regions have lost access to irrigation water. Additionally, the quality of feed is often inadequate (with limited access to high-quality feed), which restricts production growth in the sector. Another critical aspect is genetics. Ukraine has limited use of high-performing livestock breeds, and modern genetic programs are underdeveloped, hindering opportunities to improve productivity (Shahini *et al.*, 2023). Technological factors are equally important, as many farms utilise outdated equipment, preventing the implementation of modern technologies. Farmers must now also focus on energy efficiency, as blackouts can not only cause damage to farms but also completely halt their operations, as livestock cannot survive for long without the necessary conditions. In addition, high costs of feed, fuel, and electricity significantly reduce the profitability of livestock farming. The lack of government support and subsidies further

complicates the situation, especially for small and medium-sized farms. There is also a problem with human capital, as young people often choose to migrate to cities or abroad, leading to a shortage of skilled workers in agriculture (Shyian *et al.*, 2023). Finally, the unstable market, with fluctuating prices for livestock products and dependence on imports, forces farmers to reduce livestock numbers or decrease production volumes, which also affects overall productivity (Lanchenko & Ivchenko, 2023).

The agricultural sector in Ukraine provides numerous examples of how agricultural enterprises can positively impact the local economic development of rural communities. For instance, Syngenta (One step closer..., 2023) has introduced innovative technologies such as the Interra Scan soil mapping service, enabling farmers to use resources more efficiently and increase yields, demonstrating an environmentally friendly approach to sustainable development. The agro-industrial holding Astarta has been actively pursuing a social policy since 2008, with projects aimed at improving rural infrastructure, supporting education and healthcare, developing culture and sports, and fostering entrepreneurship and community development. In 2019, in partnership with the international consulting company Deloitte (Ukraine), a project was implemented for the Volochysk community to identify problems, growth points, and develop and implement SMART ideas based on the collected information to improve the lives of residents; ensure transparency and openness of local government, partnerships with businesses, and activate the participation of residents in community development processes. The development of a Community Development Strategy for 2028 and the creation of niche businesses such as the "Pranuka" natural cosmetics business project and the "Eco-pig" family farm are underway. Furthermore, since 2020, the holding company, in partnership with the organisation Pact Ukraine and the charity "Light of Hope", and with financial support from the Canadian government, has been implementing a project in four territorial communities of the Poltava region (Hlobyne, Kozelshchyna, Bilyky, and Shyshaky territorial communities) and the city of Poltava. This project aims to improve the economic well-being of rural women by strengthening their economic security and enhancing their employment opportunities and

developing women's entrepreneurship. To date, 79 business projects have been financed. In May 2020, Astarta (n.d.), together with the public organisation "International Environmental Security", implemented the online project "Eco-education in Communities". The program was aimed at engaging young people in addressing environmental safety and eco-education.

Cooperative relationships in the agricultural sector also contribute to the development of local communities, which are spreading across the country. The creation of cooperatives allows small farmers to pool their resources for joint land cultivation, reducing costs and increasing incomes. This improves the economic stability of rural families and leads to a higher standard of living for the population. In the Khmelnytskyi region, a cooperative was established for the cultivation of raspberries, blackberries, and strawberries by local residents. They leased 9 ha of communal land and obtained a bank loan to purchase equipment. Thanks to the success of the cooperative, none of its members have emigrated abroad, and the enterprise plans to expand further by installing refrigeration equipment and a berry freezing station (Shtogrin, 2022). In the Poltava region, local communities are involved in beekeeping support programs, which increase the number of jobs. This has led to increased incomes for local residents and improved quality of life in rural areas (National Institute of Strategic Studies, 2023). Furthermore, some agricultural enterprises are implementing social projects aimed at developing infrastructure, education, and healthcare in rural areas. This includes investments in local infrastructure development and the provision of humanitarian aid (Areas of agricultural..., 2024). As practice shows, such investments in building schools, kindergartens, and medical facilities significantly improve the quality of life for local residents, create jobs, and enable the development of both local businesses and the village and community as a whole.

It should be noted that with the beginning of Russia's full-scale invasion of Ukraine, many companies have changed their social responsibility priorities (Kim *et al.*, 2025). For example, the agricultural holding Kernel, which had previously implemented projects such as supporting schools, medical institutions, and developing infrastructure and culture in the regions where the company operates, is now actively working to support internally displaced persons. For instance, the company has built dormitories for such displaced persons, provided communities with necessary goods and services, helped restore critical infrastructure, and contributed to the creation of new jobs (by helping to train women and displaced persons in new professions) (War changes the rules..., 2024).

Despite challenging conditions, agricultural enterprises continue to operate and support local communities. They ensure food security and support social programs, including investments in local infrastructure and the provision of humanitarian aid (Hromov, 2022). Regarding youth education, there are some initiatives underway. For example, Bayer has been collaborating with the educational master's project "AgroKebety" for five years, aiming to cultivate a new generation of Ukrainian farmers. Students undergo a six-month internship where they acquire both theoretical knowledge and practical

skills under the guidance of Bayer experts. This practical experience includes studying business operations directly at the factory and in the field. Similarly, Continental focuses on youth development through its own internship programs designed for future employment within the company. Initially, these programs focused on agronomy and engineering, but have since expanded to include other professions. Efforts are also made to improve the skills of existing specialists and to attract veterans to the sector. This is relevant in the context of the war in Ukraine, given the need for mutual support among different segments of society, as well as addressing challenges related to sustainable development.

In the context of international sustainable development, the EU has made significant contributions by integrating environmental, economic, and social aspects into agricultural production. One key focus is on high animal welfare standards, which include restrictions on cage confinement, requirements for free range access, and adequate space for animals. This promotes animal health, improves product quality, and reduces the risk of zoonotic diseases. Another important focus is on environmental sustainability: the EU supports practices that reduce greenhouse gas emissions, such as limiting intensive grazing, using biogas plants, and reducing nitrogen fertiliser use. These measures help to mitigate the negative impacts of livestock farming on soil and water resources. Simultaneously, the EU is actively working to reduce the use of antibiotics in livestock farming to combat antimicrobial resistance, promoting disease prevention through improved husbandry practices and vaccinations. This enhances food safety and prevents the spread of antibiotic-resistant microorganisms. Supporting innovation and research through programs such as Horizon Europe (European Commission, n.d.b) is of great importance. These programs fund the development of technologies to increase production efficiency and reduce environmental impact, such as using artificial intelligence to monitor animal health. The EU also supports biodiversity and landscape restoration: farmers receive financial incentives for implementing environmentally friendly practices, such as extensive grazing, which helps to preserve the diversity of local plant and animal species. Social sustainability of rural communities is supported through grants for small farmers and short supply chains – from farm to fork, which reduces the carbon footprint of products. Within the Common Agricultural Policy of the EU, a significant portion of funds is allocated to supporting sustainable practices in agriculture, where farmers receive subsidies for meeting environmental requirements such as preserving natural landscapes and limiting the use of fertilisers (European Commission, 2019). However, this represents only 5-6% of the total subsidies, with the majority going to support farmers' incomes rather than specific environmental measures.

The approach in the USA is generally similar. One of the country's primary initiatives is to reduce greenhouse gas emissions through waste management. For instance, biogas plants on farms can convert waste into energy, reducing methane emissions and providing farmers with an additional source of income. Furthermore, to reduce environmental impact, there is a strong focus on controlling

water and fertiliser use: farms optimise irrigation processes and minimise the amount of nitrogen fertilisers, which pollute water resources. Additionally, there are standards regarding animal welfare, including increased space for free range and improved indoor conditions for animals. Moreover, reducing the use of antibiotics is a priority: there are legislative restrictions on their prophylactic use, decreasing the risk of antibiotic resistance; and innovations such as digital animal health monitoring and automated feeding processes are being implemented. One of the largest financial support programs for farmers in the USA is the Farm Bill (National Sustainable Agriculture Coalition, 2018), which specialises in providing subsidies, loans, and other forms of support for the agricultural sector. Specifically, this program provides subsidies for growing major crops, crop insurance programs, and disaster relief, as well as funding for farmers transitioning to organic production. To support small and medium-sized farms, the US Department of Agriculture offers the Microloan Program, which helps cover ongoing operational costs, including the purchase of equipment and seeds. There is also the Risk Management Agency's Crop Insurance Programme, which provides insurance policies to protect farmers from losses due to natural disasters or price fluctuations.

In Europe and the USA, the development of digital technologies in livestock farming has gained significant traction. A notable example is the use of sensors to monitor environmental conditions in real time: they are used to control temperature, humidity, CO₂ levels, and other air parameters (Neethirajan, 2020). Beyond monitoring the environment, European and American farms actively utilise sensors to monitor feed and water resources, ensuring accurate feed and water delivery. This prevents deviations in animal feed intake, reduces costs, and increases resource use efficiency. European countries and the USA are investing heavily in developing "smart" farms where digital technologies are integrated into a single network, allowing data from various systems to be tracked and changes to be responded to instantaneously (Idoje *et al.*, 2021). The development of the Internet of Things and cloud-based data storage platforms enables farmers to analyse data in real time and make informed management decisions aimed at increasing productivity and reducing costs. Regarding farmer education in the context of digital technologies, this is also a crucial component of agricultural development in the country. Approaches are based on adapting farmers to new technologies and their understanding of how innovations can contribute to farm growth. Educational programs organised by agricultural universities and colleges offer courses covering modern digital technologies in livestock farming. Additionally, government and international initiatives, such as the European Agricultural Fund for Rural Development in the EU and initiatives from the US Department of Agriculture, provide financial support and professional training for farmers, fostering the adoption of digital technologies in agriculture (European Commission, n.d.a).

Therefore, conducting agricultural activities following the principles of sustainable development, and aligned with the main goals for 2030, will contribute to the rational use of natural resources, environmental conservation,

increased responsibility for the development of rural communities, and the creation of a competitive wage system and decent living conditions for local populations.

► Discussion

Sustainable development is crucial for a country's long-term well-being, encompassing economic, social, and environmental aspects. In Ukraine, promoting agricultural development within this framework contributes to food security, improved nutrition, and increased social stability by creating jobs and reducing rural-urban migration. Correlation analysis has revealed a link between indicators of agricultural sector development in regions and the standard of living of the population. Given this, promoting the development of this sector is of paramount importance in Ukraine, especially in times of war.

The current study has provided numerous examples of how Ukrainian farmers have contributed to achieving sustainable development goals in Ukraine. A similar component was described in the research of C. Nhemachena *et al.* (2020), which examined the impact of climate change on the water and agricultural sectors in Southern Africa. They noted that climate change poses a significant threat to water and food security, affecting poverty reduction and sustainable development efforts. Understanding these impacts on water and agriculture is crucial for developing resilient systems. It highlights the urgent need for pathways towards sustainable food systems and transformative solutions, particularly in Southern Africa, where decreasing rainfall and rising temperatures threaten water availability and agricultural productivity. Investments in efficient irrigation technologies are vital for adapting to limited water resources and meeting the food demands of a growing population while enhancing the resilience of water and agricultural systems is essential for sustaining agricultural productivity and achieving regional development goals (Wang *et al.*, 2024). The current study also provided examples of how Ukrainian farmers have contributed to regional development. It was concluded that the activities of these farmers have a positive impact on both the development of agriculture in the country and the ability to achieve higher levels of sustainable development.

The current research has demonstrated that local enterprises can independently contribute to achieving sustainable development at the local level through concrete actions taken by farmers. The role of achieving sustainable development goals was also highlighted by E.B. Ali *et al.* (2021). The researchers wrote that the transition to a "green" economy has significant potential to mitigate environmental, economic, and social risks, while simultaneously sustainably improving all sectors of the economy. Attention was also drawn to the role of the state in achieving such goals, and the dangers that can arise from high levels of corruption in countries implementing such approaches. The development of small-scale enterprises in the agro-industrial complex was investigated by A. Ruml *et al.* (2022). They evaluated the development of small-scale palm oil producers in Ghana and Indonesia. Indonesia has successfully implemented large-scale programs that have united small landowners and private companies, thanks to a large amount of suitable land and favourable land tenure systems. In contrast, Ghana focused on

state-owned plantations and attempted to attract private investors, but the lack of secure land tenure and traditional land control hindered agricultural investment. In other words, Indonesia's actions towards developing such small-scale enterprises proved to be more effective as they were more centralised and state-directed, enabling both farmer development and improved living standards for residents in these regions. This suggests that in Ukraine, policies aimed at regional development should be formulated centrally by the state. Politicians should develop programs focused on the development of small-scale farming in the country: this would provide a significant number of jobs in regional areas, thus improving the living standards of local populations. Given the positive impact of such farms on the more effective development of communities, the state should support the activities of agricultural producers.

The rapid development of the agricultural sector can also lead to the emergence of agrotowns, a concept explored by N. Galluzzo (2022) concerning Italy. The researcher noted that the formation of agro-towns in regions such as Calabria, Apulia, Basilicata, Sicily, and Sardinia over the past century (1900-2000) has contributed to the development of social capital, which, combined with human capital, has fostered economic growth in surrounding rural areas. The study highlighted that increasing social capital through initiatives funded by national and European authorities is crucial for strengthening interactions among all stakeholders in rural areas and agro-towns. These initiatives have transformed agro-towns from degraded areas with high underemployment in agriculture into advanced socio-economic structures. This transition has narrowed the urban-rural divide, emphasising the positive role of rural areas, especially where agro-towns are culturally dominant. As a result, some farms have become efficient enterprises with specialised production, meeting the new functional needs of rural tourism (Trusova *et al.*, 2020). Researchers have argued that, with adequate funding and support from national and European policies, the combination of social development, social capital, innovation, and investment can protect the environment and ensure sustainable economic growth in rural areas. While this research did not specifically focus on the role of government in promoting more effective local development, it is important to note that achieving results in this area is difficult without government involvement. This is because farmers may require additional support from government authorities to achieve higher levels of local development. Furthermore, interaction with local authorities is necessary to develop a comprehensive and effective plan for achieving the set goals for territorial development. Thus, through joint efforts between the state and enterprises, significantly better results can be achieved in attaining sustainable development goals.

As previously mentioned, this research did not delve deeply into the specific actions that governments can take to improve the efficiency of local farmers. However, one potential solution is the creation of cooperatives. The possibilities of agricultural development through cooperatives were explored by Y. Qu *et al.* (2023). The researchers noted that the implementation of such policies has faced numerous challenges, including declining membership, weak capital growth, talent shortages, limited-service

capabilities, low standardisation of production, and inadequate surplus distribution systems. However, there are successful regional cases that have managed to implement integrated development models and improve the situation in terms of poverty reduction. Key recommendations for addressing cooperative challenges include improving project planning, encouraging family farms and large households to join cooperatives, increasing market competition, enhancing financial management systems, and providing more comprehensive government support, including investment guarantees. An assessment of sustainable agriculture and rural development in China was conducted by S. Hu *et al.* (2022). The study revealed that areas with low levels of agricultural development and sustainability are predominantly located in mountainous regions and southeastern traditional agricultural areas with poor agricultural environments. Given the importance of ensuring that all areas of the country achieve a higher level of development over time, the researchers noted that these components have received significantly less attention than necessary. The researchers paid significant attention to the importance of achieving sustainable development goals for these areas and highlighted the need for more efficient resource use in such regions. In light of this, it was emphasised that there is a need to more actively involve the state and its representatives in achieving sustainable development goals, formulating government programs, and incentivising farmers. However, it should be noted that additional funding or other forms of incentives are essential for achieving these goals.

► Conclusions

Agriculture plays a pivotal role in the economic development of many countries, particularly those where it is the primary source of income and employment. Moreover, this sector is crucial for achieving sustainable development as it positively impacts economic growth, environmental protection, and social well-being. Environmentally sound agricultural practices reduce the sector's negative impact on the environment, including greenhouse gas emissions and the protection of water resources and biodiversity, while sustainable agriculture increases food production, ensuring food security and improving the quality and health of food. The research demonstrated that various agricultural enterprises in Ukraine have shown how agricultural activities can positively impact local communities, as exemplified by the practices of agricultural holdings such as Astarta and Kernel. Agricultural enterprises have also invested in social projects that develop infrastructure, education, and healthcare in rural communities, significantly improving the quality of life. New jobs provide stable incomes for families, and social projects support education, healthcare, and social protection. In light of this, it can be concluded that the activities of key players in the agricultural sector play a significant role in achieving sustainable development goals in Ukraine. The study also assessed the experience of EU countries and the USA regarding sustainable development policies in agriculture. It was shown that the models share many similarities, and their integration in Ukraine could significantly improve policy effectiveness in this area. A relevant area for future research is to assess the existing

opportunities to stimulate the development of the agricultural sector in Ukraine, particularly in the regions, to ensure both higher quality and more rapid development of these areas, and to ensure more effective achievement of sustainable development goals.

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►Conflict of interest

None.

►References

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► **Анотація.** Аграрний сектор є одним із основних в контексті забезпечення більш високого рівня досягнення цілей сталого розвитку в Україні. У зв'язку з цим, дослідження взаємодії даних двох складових, у тому числі на рівні регіонів, є актуальним. В рамках даного дослідження метою було оцінити те, який вплив чинить сільське господарство України на можливості досягнення країною сталого розвитку на регіональному рівні. Дослідження було зосереджено на аграрному секторі Миколаївської області. В роботі, на основі наявних статистичних даних по області та Україні в цілому, було узагальнено тенденції до зниження виробництва тваринницької продукції, описано причини, що викликають даний тренд в країні. Зокрема було зазначено, що причиною цьому стали кліматичні чинники (посухи та дефіцит води, посилений руйнуванням Каховської гідроелектростанції), технологічні обмеження, застаріле обладнання та недостатні програми розведення. Було показано, що в країні спостерігається підвищення продуктивності посівних культур в країні в цілому, але тенденція є непостійною: спочатку показник зростав, але почав знижуватися у зв'язку з повномасштабним вторгненням 2022 року. Крім того, наведено приклади соціальної відповідальності бізнесу щодо розвитку сільських територіальних громад. Також було зазначено складну взаємодію економічних, екологічних і технологічних факторів, що формують актуальні особливості розвитку Миколаївської області. Висновки, отримані в роботі, можуть бути використані представниками державної та місцевої влади для формування стратегій досягнення цілей сталого розвитку, а також підприємствами аграрного сектору для формування власних довгострокових стратегій розвитку

► **Ключові слова:** місцевий економічний розвиток; мікроекономіка; соціальна відповідальність бізнесу; місцева влада; рівень життя



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Digitalisation of financial activities of the agricultural sector under martial law

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► **Abstract.** The purpose of this study was to analyse the effects of digitalisation on improving the efficiency of financial processes in the agricultural sector under martial law. The study focused on the key technologies contributing to the development of financial processes in agriculture, such as financial technologies, artificial intelligence, blockchain, cloud technologies, and cybersecurity systems. The study found that these technologies not only enable the automation of financial processes but also provide greater transparency and security in financial management, which is critical in times of crisis. The study also examined the specific challenges and risks of digitalisation in the agricultural sector, specifically in the context of data and infrastructure security. The growing dependence on digital systems was found to increase vulnerability to cyber threats, which requires investment in improving protection and risk management systems. Particular attention was paid to the adaptation of digital technologies in the context of war, where the positive outcomes of the implementation of digital solutions for monitoring production processes, data analysis, supply chain management, and production capacity planning were noted. The study also reviewed international practices in the use of digital technologies in the agricultural sector, specifically in countries such as Israel, the United States, Germany, China, and the Netherlands, which provided an opportunity to apply best practices to ensure the stability of Ukraine's agricultural sector. The study findings

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demonstrated that the digitalisation of Ukraine's agricultural sector is a necessary step to maintain food security and economic stability in times of war but also required overcoming considerable challenges such as insufficient infrastructure, human resource shortages, and cyber threats. The conclusions pointed to the need for increased investment in digital technologies and cybersecurity, as well as the development of human resources to effectively use the latest technologies

► **Keywords:** innovative technologies; business strategies; blockchain; artificial intelligence

► Introduction

The digitalisation of financial activities has become one of the key factors in the development of many sectors of the economy, including the agricultural sector. In the modern environment, especially in the context of martial law, this trend is particularly relevant. The agricultural sector in Ukraine is a crucial source of economic stability, ensuring food security and a great share of national exports. However, its activities are considerably complicated during periods of military operations, when the risks of losses, disruption of supply chains, and financial complications become inevitable.

The relevance of digitalisation in the financial sector of the agro-industrial complex is driven by the need for more efficient and flexible management of financial resources, effective business monitoring, and quick access to finance and market data. The use of modern technologies can greatly improve the efficiency of financial processes, reducing risks through automation and the introduction of innovative approaches to financial management. Technologies such as blockchain, financial platforms for the agricultural industry, and AI-based software solutions help to ensure the transparency and reliability of financial transactions (Liutak & Baula, 2024). One of the greatest challenges facing the agricultural sector during martial law is reduced access to conventional financial resources, deteriorating lending conditions and instability of the payment system (Stender *et al.*, 2024). Conventional financial instruments may lose their effectiveness in such circumstances, which requires finding alternative solutions. Digital technologies, including online financial management platforms, mobile applications for remote financial transactions, and decentralised financial systems, may become critical to ensuring the continuity of financial processes and maintaining the profitability of agricultural businesses.

Digitalisation is a multifaceted process that encompasses not only the automation of financial transactions, but also the improvement of analytics, security, and operational management of resources (Ponomarenko & Pysarchuk, 2024). This enables businesses to increase their competitiveness and adapt to challenging economic conditions. For the agricultural sector, especially in wartime, digitalisation can be a tool to help overcome barriers and provide access to finance, increasing transparency and reducing the influence of human factors in decision-making.

Various scholars have significantly developed research in the field of digitalisation of the financial activities of the agricultural sector. J. Tingey-Holyoak *et al.* (2021) analysed the effects of automated financial accounting systems on agricultural enterprises and emphasised that the use of such systems substantially reduced losses due to human errors. In support of this, S.R. Gunitsky & M.K. Vandana-pu (2024) showed that process automation reduced the

time required to process financial data, which was critical in times of instability. T. Yu *et al.* (2018) emphasised the value of implementing blockchain technologies to ensure the transparency of financial transactions. The study showed that the use of decentralised registries helped to avoid fraud and increased confidence in financial transactions. Q. Lu *et al.* (2024) investigated the effects of digital platforms for financial management and noted that their use enabled farmers to adapt more quickly to market changes during crisis periods.

A detailed analysis of the digital transformation of agricultural finance was also conducted by R. Kausshal (2023), who emphasised the significance of integrating artificial intelligence to forecast financial flows. The researcher's findings confirmed that AI-based systems helped to reduce the risks associated with unpredictable market conditions. R. Fabregas *et al.* (2019) focused on mobile financial applications and noted that their use contributed to the increased flexibility of financial transaction management. J. Kieti *et al.* (2021) showed that digital platforms specialised for agricultural enterprises have simplified access to credit, which was a major factor in times of financial difficulties. The researchers emphasised that online lending services enabled farmers to obtain financial resources quickly. On the other hand, M. Carmela Annosi *et al.* (2020) addressed the effects of digitalisation on risk monitoring and noted that automated surveillance systems enabled faster detection of threats to business.

T. Niemand *et al.* (2021) focused on the role of government support in the digitalisation of financial transactions. The researchers emphasised that without corresponding policies and incentives from the state, the implementation of innovations can be challenging. Finally, W. Feng & R. Liu (2024) investigated the factors that hindered digitalisation in a crisis and noted that the crucial ones were infrastructure problems and lack of proper training of staff to use the latest technologies. These studies provided a basis for analysing the benefits and challenges of digitalising the financial activities of the agricultural sector and confirmed the need for an in-depth study of this issue to develop effective strategies to overcome crisis situations. However, a series of understudied aspects persists. Specifically, the issue of integrating digital technologies under martial law requires a deeper analysis, especially in terms of the adaptation of agricultural enterprises to changes in the economic environment and the effects of infrastructure challenges. The practical application of blockchain technologies to protect financial transactions and risk management is still understudied.

The purpose of the present study was to analyse the role of digitalisation in the financial activities of the agricultural sector during martial law to improve the

efficiency of management processes in this area. The objectives of the study were to analyse the challenges faced by agricultural enterprises in implementing digital financial solutions during martial law; to investigate the effects of digital technologies on risk management and financial stability of the agricultural sector; and to develop recommendations for optimising the digitalisation process in the context of the crisis.

► Materials and methods

To investigate the effects of digital technologies on financial processes in the agricultural sector of Ukraine under martial law, the study employed methods of analysis, comparison, and systematisation of data, as well as empirical research on the example of particular enterprises, namely, the agricultural holding Myronivskyi Hliboprodukt (MHP, 2023) and Kernel (n.d.). The principal materials for the analysis included statistical data on agricultural production in Ukraine for 2019-2023 (Agricultural products at constant prices, 2023), as well as financial reports of MHP and Kernel for this period. To examine digital technologies in financial management in the agricultural sector, the study analysed the use of technologies such as artificial intelligence (AI), blockchain, cloud technologies, and mobile payment platforms. The assessment of the effects of these technologies on financial processes included an investigation of their implementation in the agricultural business, specifically in terms of accounting automation, resource management, and financial results forecasting. The study also analysed the use of digital security systems that help protect data in the digitalisation of financial transactions.

The research methodology included several key stages. The first stage was the collection and processing of statistical data, specifically from the State Statistics Service of Ukraine (Agricultural products at constant prices, 2023), which reflects changes in agricultural production and the dynamics of financial indicators in the agricultural sector for 2019-2023. Using the financial statements of MHP and Kernel, the study assessed the effects of digital solutions on their financial performance, including revenues, assets, equity, and other significant financial indicators such as earnings before interest, tax, depreciation, and amortisation (EBITDA) and net profit.

The analysis of the influence of martial law on the use of digital technologies in agriculture involved examining the specifics of the transition of agricultural enterprises to online platforms for managing finances, sales, and resources. This included investigating the role of mobile applications and online platforms in attracting investment and loans, as well as the possibility of using blockchain technologies to ensure transparency and security of financial transactions. Furthermore, the modelling method was employed to develop recommendations for optimising digitalisation in the agricultural sector under martial law. Using the economic modelling method, forecasts were created to analyse the financial results of agricultural enterprises when implementing various digital technologies. This approach helped to assess possible changes in financial performance, such as cost reduction, improved resource management efficiency, and increased financial transparency.

A significant aspect of the study was the exploration of the practices of other countries, such as Israel (Netafim Quality Policy, n.d.), the United States (McVan, 2023), and Germany (AgriCon, n.d.). The study also investigated China (Wang *et al.*, 2022) and the Netherlands (Van der Hoeven, n.d.) in the use of digital technologies in crisis situations. This helped to identify opportunities for adapting their approaches to Ukraine's conditions and to propose strategies for enhancing the digitalisation of the agricultural sector in wartime. All research findings were based on the systematisation of modern technologies and their implementation in the agricultural sector. The applied methods and materials helped to comprehensively assess the role of digital technologies in the financial management of agricultural enterprises in Ukraine.

► Results

Digitalisation has become an integral part of the development of the modern economy, including the financial sector, which is undergoing significant transformations under the influence of technological innovations. The development of information technology and continuous improvement of software have changed traditional approaches to financial management, creating conditions for faster, safer and more efficient financial transactions. The concepts underpinning modern digitalisation cover various aspects, from process automation to the introduction of AI and blockchain technologies.

One of the key concepts of digitalisation is financial technology (FinTech), which combines innovative solutions for providing financial services using the latest technologies. Research shows that the implementation of FinTech solutions can reduce the cost of financial transactions by up to 30% and increase revenues by 20% by automating processes and improving access to services such as mobile banking apps, online lending, and digital payment systems. AI and machine learning are already actively helping financial institutions automate decision-making: AI analyses large amounts of data to assess credit risks, predict financial trends, and identify suspicious transactions, which can reduce credit risks by 20%. Blockchain technologies also contribute to major cost reductions in the financial sector (up to 50% in some cases), ensuring transparency, security, and decentralisation of transactions, as they allow conducting transactions without intermediaries (Mhlanga, 2021).

Cloud technologies have become another integral element of modern financial digitalisation, helping companies scale operations and reduce infrastructure costs by 15-20%. Cloud-based solutions enable financial institutions to ensure continuity of operations and quick access to large amounts of data, which is crucial in the current market environment (Javaid *et al.*, 2022). For the agricultural sector, which faces many financial challenges, digital technologies have become a key tool for improving the efficiency of financial management. Automated accounting and reporting systems, for instance, can reduce administrative costs by up to 25% by simplifying data processing and improving accounting accuracy (Gotthardt *et al.*, 2020). Online platforms enable access to finance without the need to visit physical offices of banks or financial institutions, which is especially valuable in remote

regions. Mobile applications and web services help farmers apply for loans, negotiate with suppliers, and monitor the financial status of their farms in real time. The use of AI in financial processes enables better working capital management, prompt response to market changes, and minimisation of losses (Ahamed & Vignesh, 2022). Big Data analytics systems help farmers better understand market trends, which is vital for cost and investment planning.

Despite the major benefits, there are some challenges associated with digitalisation in agricultural finance. The key ones include insufficient infrastructure in remote regions, lack of trained professionals to work with the latest technologies, and cybersecurity risks. Digitalisation has become the primary driving force behind the transformation of various sectors of the economy, including the financial and agricultural sectors, in periods of stability and development. However, in times of crisis, such as wars, economic recessions, or natural disasters, the role of digital technologies becomes particularly critical. Digitalisation can be both a reliable tool for adaptation and effective functioning and a source of new challenges and risks that require special attention. The need to maintain infrastructure is also a prominent aspect, as even the best digital platforms cannot function without stable networks and servers. In crises, when infrastructure is often disrupted by hostilities, natural disasters, or technical malfunctions, access to significant digital systems may be limited (Moşteanu *et al.*, 2020).

One of the most successful digitalisation practices in Ukraine's agricultural sector is the introduction of blockchain technologies to ensure transparency of accounting and financial transactions. For example, Ukrainian agricultural cooperatives such as GrainChain use blockchain to create decentralised registries that guarantee the accuracy and traceability of transactions. This greatly reduces the risk of fraud and simplifies the audit process, while increasing the trust of investors and international partners. Automation of financial processes through digital platforms has become the basis for agricultural enterprises to adapt to the challenges of martial law. For instance, the AgriAnalytica system operating in Ukraine allows farmers

to keep track of expenses, apply for loans, and analyse financial performance in real time.

Artificial intelligence and analytical systems have also become a valuable tool for financial management. For instance, the Ukrainian company SmartFarming uses AI to forecast yields, model risks, and plan financial flows. Big Data analytics allows farmers to better understand market trends, which contributes to rational cost and investment planning. Another successful example is the use of cloud platforms to manage agricultural processes. Thanks to cloud solutions such as Cropio, agricultural companies can remotely monitor crop conditions, allocate resources, and analyse financial results. The role of digital technologies in strengthening financial inclusion is particularly noteworthy. For example, cooperatives that implemented digital platforms for transparent payments between farmers and suppliers can increase the efficiency of their cash flow and ensure prompt payment for services and products. This not only reduced financial risks but also helped to strengthen cooperation in times of economic instability (Bexxolli *et al.*, 2023).

The digitalisation of Ukraine's agricultural sector under martial law has become a critical tool for preserving food security and maintaining stability in the agricultural sector. Since the outbreak of the war in 2022, Ukrainian farmers have faced many challenges, such as disrupted supply chains, damaged infrastructure, reduced access to finance, and a shrinking workforce. In such circumstances, digital technologies have helped agricultural enterprises adapt to the new reality, optimise production and financial processes, and ensure connection with internal and international markets. Automation of financial accounting and the use of blockchain have increased the transparency and security of financial transactions, which is crucial when attracting investment and interacting with international partners. The introduction of digital technologies made it possible to maintain the key indicators of the agricultural sector even in wartime (Sirenko *et al.*, 2021). The analysis in Table 1 presents how the agricultural accounts have evolved to overcome the current challenges.

Table 1. Economic accounts of agriculture for 2019-2023, UAH mln

Indicators	Year				
	2019	2020	2021	2022	2023
Agriculture output	842,767	892,852	1,366,456	1,073,916	1,163,676
of which					
Crop production	623,951	670,423	1,100,168	811,056	904,630
Animal husbandry	200,990	203,942	237,586	243,599	240,833
Services	13,097	13,457	21,615	14,905	18,213
Intermediate consumption	498,744	511,460	789,635	636,962	621,124
Gross value added	344,023	381,392	576,821	436,954	542,552
Net profit	229,467	253,353	401,295	318,775	380,122

Source: created by the authors of this study based on Agricultural products at constant prices (2023)

Agricultural output over the five years shows fluctuations, with an overall decline in 2022, when output declined because of the adverse impact of the war, including lower yields and loss of production capacity. Despite the major decline in agricultural output in 2022, thanks

to the introduction of digital solutions, farms managed to maintain financial stability and begin to recover in 2023. Farms that have implemented digital financial management platforms have recorded a 10-15% increase in revenues due to more efficient use of resources and cost

optimisation. This helped companies not only to maintain liquidity but also to restore production capacity. In 2023, a 20% reduction was observed in management process costs due to accounting automation and the use of cloud technologies, which contributed to the stability of financial operations in a high-risk environment. At the same time, the cost of administrative services was reduced thanks to FinTech solutions that ensured more efficient interaction with banks and suppliers (Nechyporenko *et al.*, 2022).

One of the main achievements in the introduction of digital technologies was the automated management of financial processes. During the war, many farmers managed to switch to online platforms to manage their finances, which enabled them to make quick payments, apply for loans, and make international payments without having to physically visit banks or other financial institutions. This was a significant factor in maintaining the financial stability of the business when conventional methods of making payments in the economy became less efficient. Businesses that switched to online platforms reduced their operating costs for financial services by an average of 20-25%, which was a crucial factor in maintaining financial stability during the crisis (Myronchuk *et al.*, 2023).

Digital platforms have also helped to keep producers and consumers connected. Online trading platforms and commodity exchange platforms enabled farmers to sell their products even in the challenging conditions of the war. This has become a valuable tool for maintaining the sales market, particularly in the face of restricted logistics routes and problems with physical transportation of products. Online sales have enabled agricultural businesses not only to minimise losses but also to maintain sales markets even in an unstable economic environment. Around 30% of farmers who used these platforms managed to retain up to 40% of their sales markets even in the face of active hostilities. Online sales have become a tool that has allowed businesses to minimise losses and maintain stable financial flows (Yekimov *et al.*, 2022). However, despite these advantages, the implementation of digital solutions in the agricultural sector in wartime has certain challenges. One of the key challenges is the uneven access to digital technologies in various regions of the country. In remote areas, especially in the east and south, where hostilities are active, the infrastructure is heavily damaged, making it challenging to use the latest technologies. Many farmers do not have adequate access to a stable internet connection or are unable to implement digital solutions due to a lack of resources or support.

Another barrier to the development of digitalisation is the shortage of human resources. Effective implementation of the latest technologies requires skilled professionals who can work with digital platforms, analytical systems, and other tools (Morosan & Bowen, 2022). However, the war has led to a massive emigration of young professionals, while those who stayed often lack sufficient experience to work with modern digital technologies. This makes it even more challenging for farmers to adapt to new conditions. Cybersecurity risks have also become a genuine issue. The growing digitalisation of the agricultural sector increases the probability of attacks on information systems, which can lead to the loss of valuable data or

financial resources. As Ukraine's cybersecurity infrastructure still needs to be improved, farmers could suffer major losses in case of successful cyberattacks.

Financial instability is a barrier to the adoption of digital solutions. Many agricultural enterprises, especially small and medium-sized ones, have limited access to finance for technology development due to the overall economic situation in the country. This means that even the best digital tools may be unaffordable for a great proportion of farmers due to their prohibitive cost (Agrawal *et al.*, 2019). Digitalisation in the agricultural sector becomes a vital area of focus in times of crisis, especially during war or natural disasters. Countries with varying economic and social conditions leverage technology to support food security and reduce risks to agricultural production (Dovgal *et al.*, 2017). The practices of other countries can give insight into which strategies can increase the resilience of Ukraine's agricultural sector in wartime.

Israel is a vivid example of the effective use of digital technologies to manage financial activities in the agricultural sector, specifically in resource optimisation. In 2021, the Israeli company Payoneer launched an online platform for managing international financial transactions of farmers, which reduced transaction costs and provided faster access to capital for farmers (Netafim Quality Policy, n.d.). This is a valuable experience for Ukraine, where digital platforms for financial management are becoming increasingly relevant, especially in times of crisis when conventional financial instruments may be limited.

In the United States, a strong emphasis on digital technologies has been placed on financial security. Cybersecurity programmes for agricultural companies, especially after the cyberattack on the largest meat processing company JBS Food, helped reduce the risks of cyberattacks on agricultural companies by 35% in the first year after implementation. This helped ensure the stability of financial flows and operations (McVan, 2023). For Ukraine, this experience is significant, as protecting farmers' financial platforms from cyberthreats is critical to maintaining financial stability in wartime.

Germany has been actively implementing digital technologies to optimise financial processes during the COVID-19 pandemic. Specifically, the creation of AgriCon online platforms enabled farmers to effectively manage financial transactions, optimise orders, and logistics costs. This reduced the cost of transporting products by 15% and allowed farmers to stay afloat even in the face of crisis restrictions (AgriCon, n.d.). For Ukraine, such platforms could become valuable tools to maintain stable financial operations during the war, including optimising logistics costs and ensuring financial flexibility.

China is investing in automation to reduce labour costs, which also directly influences the financial performance of agricultural companies. The use of unmanned tractors and autonomous mechanisms in rural areas can reduce labour costs by 25-30%, which positively influences financial efficiency (Wang *et al.*, 2022). In Ukraine, the introduction of such automated solutions could reduce labour costs and increase the efficiency of financial resources, especially in areas where access to labour is limited.

The Netherlands, which is a global leader in the use of automated technologies, is also actively implementing

digital solutions to manage financial flows in the agricultural sector. The introduction of automated greenhouse technologies allows agricultural enterprises to significantly reduce energy costs and increase productivity, which improves financial outcomes (Van der Hoeven, n.d.). For Ukraine, analogous solutions could be significant for reducing natural resource costs and increasing the financial

sustainability of agricultural companies in challenging conditions. The practices of other countries in implementing digital technologies in the agricultural sector during crisis situations is an example for Ukraine. Table 2 presents the practices of other countries in digitalising the agricultural sector in times of crisis and how these practices can be applied in Ukraine.

Table 2. Countries' experience in digitalising the financial activities of the agricultural sector in crisis conditions

Country	Digital solutions	Challenges and opportunities for application	Recommended measures
Israel	Online platforms for international financial transactions	Lower transaction costs, faster access to capital; need for scalable solutions for small and medium-sized enterprises	Create local digital platforms for financial transactions; train farmers to use such tools
USA	Cybersecurity of financial platforms	Growing cyber threats, the need for cyber defence specialists and modern software	Implementation of state cyber defence programmes; training of personnel and creation of technical audit programmes for systems
Germany	Digital platforms for financial management	Insufficient access to the Internet in rural areas; need for financial flexibility in times of crisis	Developing online platforms for financial management; providing access to high-speed internet
China	Automated financial tools to reduce costs	Excessive cost of equipment, need for qualified specialists	Support for local software developers; training for farmers and technicians
Netherlands	Digital solutions for financial monitoring of greenhouses	Need to invest in equipment; dependence on stable energy supply	Integration of financial monitoring into automated systems; promotion of renewable energy sources

Source: created by the authors

Table 2 systematises the principal approaches and technologies used in various countries and suggests possible ways to adapt them to Ukrainian conditions to support the resilience of the agricultural sector in crisis circumstances. The experience of implementing digital solutions is significant not only at the industry level, but also at the level of individual companies that are actively integrating modern approaches into their operations. Myronivskyi Hliboprodukt is one of the largest agricultural producers in Ukraine. Over the 5 years (2019-2023), MHP's

financial activities have been focused on modernising equipment, expanding production and diversifying products. The company has invested heavily in the development of innovative technologies, including digital solutions that help optimise resource management, specifically agricultural assets, and increase productivity. In an increasingly competitive global environment, MHP delivers stable revenues and provides important opportunities for the country's economy. Table 3 shows the company's financial performance.

Table 3. MHP's financial performance indicators for 2019-2023, USD mln

Indicators	Year				
	2019	2020	2021	2022	2023
Income	2,056	1,911	2,372	2,642	3,021
Profit	215	-133	393	-231	142
EBITDA	378	340	648	384	445
Assets	2,509	2,108	4,014	3,809	3,886
Capital	1,596	1,254	1,794	1,446	1,567

Source: created by the authors of this study based on MHP (2023)

MHP's financial performance demonstrates that the company has managed to overcome the challenges posed by both the pandemic and the war. While the company's revenues and assets are growing, profitability is more volatile, reflecting the impact of the crisis on financial performance. The recovery in EBITDA and equity in 2023 suggests a gradual stabilisation, while the overall growth

in assets shows the company's ability to adapt effectively to changing circumstances.

Kernel agro-holding is one of the leaders in the Ukrainian agricultural sector, actively investing in the modernisation of its production facilities and the development of digital technologies to improve the efficiency of agricultural asset management, specifically in finance and

resources. In the face of major economic challenges, including the pandemic and the war, Kernel has managed to adapt and maintain stability through the introduction of

innovative digital solutions such as FinTech, blockchain, and cloud technologies. Table 4 shows the company's financial performance.

Table 4. Kernel's financial performance indicators for 2019-2023, USD mln

Indicators	Year				
	2019	2020	2021	2022	2023
Income	3,960	4,107	5,596	5,332	3,455
Profit	179	123	513	-41	299
EBITDA	346	443	806	220	544
Assets	2,464	3,165	3,997	4,186	3,885
Capital	1,346	1,494	1,949	1,686	1,744

Source: created by the authors of this study based on Kernel (n.d.)

Kernel's financial performance in 2019-2023 demonstrates the overall resilience of the business despite the influence of the crises. The company's revenues grew until 2021, followed by a decline in 2023 caused by the effects of the war. Profitability is a volatile indicator: the company suffered losses in 2022 due to the crisis, but in 2023, profits increased. EBITDA shows a steady recovery after a drop in 2022. Since the outbreak of war in Ukraine, agricultural holdings, including MHP and Kernel, have faced serious challenges. Part of the production facilities of both companies are in the regions affected by the hostilities, which led to a loss of resources, disruption of supply chains and logistical difficulties. For Kernel, the war has made it challenging to export its products due to the blockade of sea-ports, forcing the company to reorient its supplies through alternative routes, increasing transport costs. Risks for both companies have increased due to higher logistics costs, limited access to markets and delays in cash flows caused by restrictions on working with foreign investors. However, both companies have adapted to the unfamiliar environment by focusing on the internal market and looking for alternative supply and sales routes.

Digitalisation has become a key area of development for both MHP and Kernel, especially in wartime. MHP actively leverages IoT technologies, analytical platforms, and ERP systems to monitor resources, manage production, and financial flows. Kernel is implementing digital solutions to improve supply chain management, logistics, and finance, which enables the company to minimise losses and stay competitive. For example, Kernel's use of Big Data technologies helps to analyse market trends, optimising export operations and planning. During the crisis, both companies also invested in cybersecurity to protect data and ensure the stability of financial transactions. As a result, MHP and Kernel have not only managed to reduce operating costs, but also considerably improve the efficiency of their resource management, even in times of economic instability. The companies have considerable potential to improve their financial performance by implementing digital solutions, which will optimise operations and mitigate the risks caused by martial law. A digitalisation strategy can cover several key areas aimed at increasing the efficiency of resource management, enhancing analytics capabilities, improving logistics, optimising financial operations, ensuring cybersecurity, and strengthening customer relationships.

The first area of the strategy is digital optimisation of resource management. Companies can automate resource monitoring and management processes using IoT. This will enable them to quickly assess the need for fertilisers, water, and energy, reducing production costs by 5-10%. Integration of ERP systems to automate cost accounting, inventory management, and forecasting of resource requirements will reduce costs by 7-15% by optimising financial flows and reducing losses. The second area is the expansion of analytics and forecasting based on Big Data. Using analytical platforms to process data from various sources, such as weather conditions and market fluctuations, will allow companies to assess risks more accurately and make informed financial decisions. The use of machine learning for financial forecasting will reduce the probability of financial losses from unforeseen factors by 20-25% and optimise investment planning. The third area concerns the improvement of logistics. The use of digital platforms for logistics management and tracking of delivery routes will help choose the best delivery routes, reducing transport costs by 5-10% even in conditions of limited access to territories. Automation of logistics processes through integration with suppliers will help ensure supply stability and reduce logistics costs by an average of 7-12%.

Another prominent area of the strategy is the introduction of financial digital platforms for cash management and investment attraction. The introduction of electronic payments and mobile banking will enable efficient management of working capital, reducing the processing time of financial transactions by 15-20%, which will positively influence the company's liquidity. Online platforms for attracting investments will provide further access to financing, especially in the case of hindered access to conventional loans. This can increase the volume of attracted investments by 10-15% per year. Considering the growing cyber risks during martial law, strengthening cybersecurity is a critical area. Investments in modern cyber security and access control systems, along with staff training, will reduce the risks of cyber incidents by 30-40%, which will protect financial information and reduce possible financial losses from attacks. The last area is the implementation of CRM systems to maintain relationships with customers and partners. This will increase the transparency of operations with customers and strengthen relations in international markets, which will ensure stable demand for

companies' products even under the restrictions caused by the war. Automation of marketing processes through CRM will help to better respond to changing market demands and can increase sales by 10-12% through more accurate targeting and personalisation. Taken together, these strategic areas of digitalisation could allow MHP and Kernel to reduce operating costs by 20-25%, increase resource efficiency, and greatly improve financial outcomes even in the face of economic and security instability. Implementing these areas of digitalisation will allow companies to optimise costs, reduce risks associated with market fluctuations and war, and maintain competitiveness. As a result, the company will be capable of maintaining stable financial performance, ensuring economic sustainability, and implementing a long-term growth strategy even in the face of significant external challenges.

► Discussion

The findings of the present study suggest that the introduction of digital technologies in the financial activities of the agricultural sector has major potential for optimising operations and managing risks. One of the key advantages is the automation of financial processes, which greatly reduces the amount of manual work and reduces the probability of errors. This enables farmers to obtain more accurate data on financial flows, monitor expenses and income, which helps them make more informed management decisions. This is crucial during periods of instability, such as martial law, when prompt and accurate data play a key role in maintaining business. H. Tian *et al.* (2019) investigated the automation of financial processes in the agricultural sector and noted that digital solutions reduce the risk of errors and improve cost management. The researchers also noted an increase in productivity due to the minimisation of manual work, which is consistent with current findings. U. Kambali & N. Panakaje (2022) emphasised that automation is not crucial for all agricultural enterprises due to the excessive cost of implementation, which only large farms can afford. Therefore, this opinion can be partially agreed with, as the current findings suggest that even small farmers can benefit from digitalisation, but this requires adapted and cheaper solutions.

The use of artificial intelligence and Big Data helps agricultural enterprises anticipate possible risks and adapt financial strategies to market conditions (Llazo *et al.*, 2024). For example, Big Data analytics can predict changes in the market, analyse weather conditions, and other factors that may affect yields. Combined with automation, this approach enables farmers to reduce losses and optimise the use of resources. However, the complexity of implementing such technologies often requires highly skilled professionals, which are lacking in rural regions of Ukraine, limiting the possibilities for the widespread of such solutions. R. Ben Ayed & M. Hanana (2021) explored the use of artificial intelligence to monitor and manage yields in the agricultural sector. The researchers emphasised that the use of artificial intelligence algorithms allows optimising the use of resources, such as water and fertilisers, and increasing yields. These conclusions are in line with current findings, as the potential of digital technologies to improve the efficiency of agricultural processes was also noted.

One of the key aspects of the effects of digitalisation is the introduction of blockchain technologies that ensure transparency and security of transactions, reducing the risk of data falsification (Gulaliyev *et al.*, 2023). This is crucial for financial transactions involving large amounts of money or investment. However, due to the martial law, agricultural enterprises in Ukraine face limited access to resources and infrastructure to support such technologies, which creates further obstacles. S. Rijal & F. Saranani (2023) focused on the use of blockchain technologies to ensure transparency of financial transactions. The researchers pointed out that blockchain avoids data fraud and increases trust in financial transactions, especially when attracting investment. This is consistent with current findings, which also highlighted the significance of transparency in crises. However, the researchers believe that blockchain is too complicated to implement due to the unstable infrastructure and may be relevant only for large enterprises. The present study suggested that blockchain can also be used by medium and small farmers, provided that the platforms are simplified. H. Zhou *et al.* (2019) focused on Big Data analysis in risk forecasting. The researchers concluded that although the use of big data helps to adapt financial strategies, its practical implementation in crisis conditions is limited due to unstable infrastructure and lack of qualified personnel. The current findings also addressed the problem of a lack of specialists in rural areas, which confirms the conclusions of H. Zhou *et al.* However, the development of distance learning and government support may reduce this drawback in the future.

The martial law has also brought major challenges to the infrastructure of the agricultural sector. Due to the partial destruction of transport routes and logistics networks, farmers are forced to adapt their processes to the new conditions. In this context, digital platforms for selling and purchasing products are becoming indispensable to keep producers and consumers connected. Thanks to online trading, farmers can minimise losses while maintaining the ability to sell their products even when they have limited access to conventional markets. This is especially significant in times of economic instability when direct access to financial and logistical resources may be limited. K. Sermuksnyte-Alesiuniene *et al.* (2021) investigated the effects of digital solutions on logistics optimisation in crisis conditions and argued that online trading allows farmers to circumvent problems with physical access to markets. This is in line with current findings that digital platforms help to keep producers and consumers connected, even when conventional logistics are unavailable. M. Remondino & A. Zanin (2022) noted that digital platforms also have their limitations, specifically, the risk of unstable Internet access in remote regions. It is worth agreeing with this observation, although the development of mobile internet and government support can help overcome these limitations.

Cybersecurity is another critical aspect of digitalisation in crises. The growing dependence on digital solutions creates new vulnerabilities for the agricultural sector (Mukambaeva *et al.*, 2024). The risk of cyberattacks and hacking is becoming a reality for many farms, especially in the context of armed conflict. The US practices in managing cybersecurity in agriculture, which has become a

priority after cyberattacks on large agricultural companies, could be useful for Ukraine. Successful adaptation of practices from other countries will help to enhance the security of Ukrainian farmers working with digital platforms. S. Rotz *et al.* (2019) emphasised the value of cybersecurity in the agricultural sector due to the growing dependence on digital technologies. The researchers also argued that agricultural companies must invest heavily in cyber defence, as the risk of cyberattacks increases under martial law. The researchers noted that farmers should develop their own cybersecurity standards, which is different from the approach of using existing solutions. K. Demestichas *et al.* (2020) also focused on cybersecurity risks but suggested that international practices and off-the-shelf solutions for the agricultural sector should be used, which is in line with the findings of the present study.

It is worth noting the positive experience of other countries that actively use digital solutions in the agricultural sector. For example, Israeli systems for water management or Chinese automated tractors for soil cultivation have become indispensable elements of resilience in crisis situations. For Ukraine, these practices can serve as a basis for developing its own solutions, which will help reduce dependence on labour and improve resource management in remote or hazardous areas. A. Ferrari *et al.* (2020) investigated the influence of digital technologies on the socio-economic development of rural communities. The researchers concluded that digitalisation contributes to improving the quality of life in rural areas by creating new jobs and improving access to educational and financial resources. The researchers also noted that digitalisation promotes greater integration of rural communities into the national and international economy, which is consistent with present findings. However, in contrast, A. Ferrari *et al.* paid more attention to cultural barriers that may hinder the rapid adoption of digital technologies in remote villages, where residents may be less ready for innovative approaches. In summary, digitalisation of the agricultural sector is a crucial area for Ukraine, especially in times of crisis. However, systematic investments in infrastructure, cybersecurity, and human resources development are required to fully exploit the potential of digital technologies. Adopting international practices and adapting it to Ukrainian conditions will contribute to the stability of the agricultural sector and increase its efficiency in the face of instability.

► Conclusions

The study highlighted the significance of digital technologies for the financial activities of the agricultural sector, especially in times of crisis, including in Ukraine. The use

of blockchain technologies ensures transparency and security of financial transactions, which is critical for large transactions. Cloud technologies can reduce infrastructure costs, while maintaining access to large amounts of data and allowing operations to scale.

Digitalisation in the agricultural sector facilitates the automation of financial accounting, which reduces costs and increases efficiency. In Ukraine, this is particularly relevant under martial law, when conventional management methods are becoming less effective. Online platforms for financing, lending, and insurance enable farmers to operate without having to physically visit banks, which is essential for remote regions. Specifically, the introduction of online platforms has reportedly reduced the cost of processing financial transactions by 20-30%.

The practices of other countries demonstrated the effectiveness of digitalisation of financial activities in the agricultural sector. Israel is implementing platforms for managing international financial transactions that reduce costs and provide access to capital. The US focuses on cyber security of financial platforms, reducing the risk of attacks and ensuring the stability of financial flows. In Germany, online platforms are optimising logistics costs to support farmers in crises. China is investing in automation, reducing labour costs, while the Netherlands is using technology to reduce resource consumption and increase productivity. These practices can be useful for Ukraine to reduce costs and improve the financial sustainability of farmers.

Strategic areas of digitalisation can allow MHP and Kernel to reduce operating costs by 20-25%, increase resource efficiency, and markedly improve financial outcomes even in the face of economic and security instability. Overall, digital technologies such as automated accounting systems, online platforms for financial transactions, precision farming technologies, and blockchain help to improve the efficiency of the agricultural business. The limitations of the present study included the lack of available data on the internal processes of agricultural companies and the limited ability to assess the long-term effects of digitalisation in the context of the military crisis. Further research could be aimed at analysing the effectiveness of concrete digital solutions in the agricultural sector and examining their impact on the financial sustainability of enterprises in crises.

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► Conflict of interest

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► References

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Цифровізація фінансової діяльності аграрного сектору в умовах воєнного стану

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► **Анотація.** Дане дослідження було направлене на аналіз впливу цифровізації на підвищення ефективності фінансових процесів в аграрному секторі в умовах воєнного стану. Акцентовано увагу на основних технологіях, що сприяють розвитку фінансових процесів у сільському господарстві, таких як фінансові технології, штучний інтелект, блокчейн, хмарні технології та системи кібербезпеки. Виявлено, що ці технології не тільки дозволяють автоматизувати фінансові процеси, але й забезпечують більшу прозорість та безпеку в управлінні фінансами, що є критично важливим під час кризових умов. У роботі також розглядалися специфічні виклики та ризики цифровізації в аграрному секторі, зокрема, у контексті безпеки даних та інфраструктури. Виявлено, що зростаюча залежність від цифрових систем збільшує вразливість до кіберзагроз, що потребує інвестицій у вдосконалення систем захисту та управління ризиками. Особливу увагу приділено адаптації цифрових технологій в умовах війни, де відзначено позитивні результати впровадження цифрових рішень для моніторингу виробничих процесів, аналізу даних, управління ланцюгами постачання та планування виробничих потужностей. У роботі також вивчено міжнародний досвід використання цифрових технологій у аграрному секторі, зокрема в таких країнах, як Ізраїль, США, Німеччина, Китай та Нідерланди, що надає можливість застосувати найкращі практики для забезпечення стабільності аграрного сектору України. Результати дослідження демонструють, що цифровізація аграрного сектору України є необхідним кроком для підтримки продовольчої безпеки та економічної стабільності в умовах війни, але також вимагає подолання значних викликів, таких як недостатня інфраструктура, кадровий дефіцит та кіберзагрози. Висновки вказують на необхідність посилення інвестицій у цифрові технології та кібербезпеку, а також розвиток кадрового потенціалу для ефективного використання новітніх технологій

► **Ключові слова:** інноваційні технології; бізнес-стратегії; блокчейн; штучний інтелект



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Application of artificial intelligence to improve the economic efficiency of land use management in the agricultural sector

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► **Abstract.** The purpose of the study was to assess the cost-effectiveness of using artificial intelligence (AI) to predict environmental changes in land use and optimise agricultural production. It was determined that the introduction of machine learning and big data analysis algorithms can significantly improve the accuracy of forecasts of agricultural land conditions, optimise the use of resources, including fertilisers and water, and reduce costs. The study analysed how AI can contribute to a more rational choice of crops and planning of sowing and harvesting, which has a positive impact on yields. In addition, the study addressed the environmental aspect: the use of AI can reduce the negative impact on the environment through precise resource management and reduced soil and water pollution. The work included modelling yields for different climate scenarios, which allows forecasting possible outcomes and developing adaptive strategies for the sustainable development of Ukraine's agricultural sector. The study demonstrated that the introduction of AI in the Ukrainian agricultural sector contributes to the improvement of land use efficiency, allowing farmers to respond more quickly to changing climate conditions. Machine learning algorithms, including those based on the analysis of

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data collected from satellite images and sensors, can help determine the timely need for fertiliser and water, which ensures the rational use of resources and reduces production costs. The forecasting models used in the article reflect possible yield scenarios for the period 2025-2028 for different climatic conditions, which allows enterprises to better plan agrotechnical measures and minimise risks. Thus, the study results emphasised the importance of AI as a tool for long-term strategic planning in the agricultural sector

► **Keywords:** yield forecasting; agriculture; data analysis; innovation; machine learning

► Introduction

The relevance of studying the use of artificial intelligence (AI) to improve the economic efficiency of land use management in the agricultural sector is driven by the growing challenges associated with landscape change, urbanisation, land degradation and the need for rational water management. Modern environmental problems, exacerbated by global climate change and population growth, require the search for innovative approaches to preserve natural resources and optimise the use of agricultural land. AI opens up new opportunities for analysing large amounts of data and predicting the effectiveness of various land use decisions, which allows for a balance between economic benefits and preserving environmental balance.

The study by R. Espinel *et al.* (2024) demonstrated how AI helps to optimise the management of agricultural land by accurately calculating fertilizer doses. This allows not only to reduce the use of chemicals but also to increase the efficiency of their application, which has a positive impact on economic results and the ecological state of the land. Y. Peng *et al.* (2019) focused on the use of predictive models to optimise irrigation. Thanks to AI technologies, farmers can use water resources more rationally, which, in turn, reduces irrigation costs and ensures stable yields even under changing climatic conditions.

The study by R. Ben Ayed & M. Hanana (2021) indicates a significant economic benefit from the introduction of AI in agricultural cost planning. Accurate allocation of resources based on AI forecasts helps to reduce costs and increase profitability, making the agricultural business more sustainable. R. Singh *et al.* (2020) explore the possibilities of automated soil monitoring systems that use AI to track the level of land degradation. This allows for timely detection of problems and the necessary measures to preserve soil quality, ensuring their long-term fertility.

M.Y. Shams *et al.* (2024) highlighted the benefits of crop rotation forecasting using AI algorithms. This allows agricultural enterprises to optimise the use of land for certain crops, improving their productivity and reducing the risk of soil depletion, which contributes to the economic stability of the farm. K. Jha *et al.* (2019) noted the importance of automating crop quality control through AI systems. AI's ability to identify problems at the stage of growing and harvesting helps to improve product quality, which is important for market-oriented agricultural enterprises.

L. Chen *et al.* (2023) investigated the effectiveness of AI technologies in reducing the risks associated with changes in weather conditions. AI helps to quickly adapt to unfavourable weather factors, which helps to avoid significant crop losses and maintain production stability. İ. Yağ & A. Altan (2022) analyse the benefits of AI in the selection of plant protection products. This allows reducing the use of chemicals and, at the same time, ensures high efficiency of

crop protection, which has a positive impact on the environmental and economic performance of the enterprise.

S.A. Bhat & N.-F. Huang (2021) show how the use of big data and AI technologies allows agricultural enterprises to plan yields under different climatic conditions. This provides more accurate forecasts and stable financial performance, which helps minimise risks in the agricultural sector. M.J. Usigbe *et al.* (2024) noted that AI technologies make the agricultural sector more resilient to environmental and economic challenges. It helps to reduce losses, improves resource management, and increases the economic efficiency of agricultural enterprises, which is especially important for the long-term development of the industry.

Thus, researches demonstrate the effectiveness of using AI to predict land use changes, particularly in the agricultural sector. An important aspect is the forecasting of land degradation, changes in water resources, and the impact of anthropogenic activities on protected areas. Therefore, researching effective AI-based solutions for monitoring and managing these processes is key to ensuring sustainable development of the agricultural sector and conservation of natural resources. However, the use of AI to increase economic efficiency in the agricultural sector remains insufficiently studied. Also, the impact of integrated AI algorithms on land use management, taking into account climate conditions, has not yet been fully investigated.

The purpose of the study was to analyse the application of AI to improve the economic efficiency of land use management in the agricultural sector. The main tasks include: analysing AI capabilities for yield forecasting; researching AI algorithms, including machine learning, adapted to the needs of the agricultural sector; developing recommendations for optimising land use processes.

► Materials and methods

The study on the application of AI to improve the economic efficiency of land use management in the Ukrainian agro-industrial complex used various methodological approaches and materials to analyse the impact of innovative technologies on agricultural productivity and its resilience to environmental challenges. Firstly, secondary data from the State Statistics Service of Ukraine (n.d.) was used to collect data on the state of the agricultural sector, which provided information on the yields of major crops in Ukraine for the period 2017-2023. This data allowed to analyse the yield dynamics, identify the main trends, and identify the need to optimise agronomic practices, in particular in the context of AI implementation. Google Colab was used to forecast the yields of major crops for the period 2024-2028, which allowed the company to consider historical data and model various development scenarios. For this purpose, a model was considered that includ-

ed optimistic, moderate and pessimistic scenarios that provided for different rates of growth or decline in yields depending on expected conditions and possible changes in the industry.

The study also examined big data analytics, which allows for the analysis of data on the condition of agricultural land, in particular using satellite images and sensor data. In addition, to assess the impact of the introduction of the latest technologies on the economic efficiency of agricultural enterprises, comparative analyses were conducted on the example of specific companies that have implemented AI-based solutions. Projects and platforms that demonstrate practical experience in implementing innovative technologies to improve the efficiency of land use and agriculture were also reviewed. In particular, considerable attention was paid to IBM's Watson solution, which uses AI to analyse large amounts of agricultural and climate data. Precision Agriculture, a platform that implements the concept of precision farming by using sensor data, satellite images, and GPS navigation, was also discussed. Smart Farming project, which provides comprehensive real-time monitoring of agricultural land. Agreeana, which focuses on the implementation of carbon farming principles, in particular on approaches that help reduce the carbon footprint of the agricultural sector. Agrilab, which provides opportunities for detailed soil analysis to increase yields.

Another important aspect of the study was the environmental factors associated with changes in land use. The analysis of changes in natural landscapes, land degradation, and water pollution made it possible to identify the main environmental risks arising from intensive land exploitation. AI technologies were assessed in terms of their potential to reduce the negative impact on the environment, in particular by increasing the efficiency of natural resources use. As a result, the key recommendations for the implementation of AI in land management were considered, including the need to create an infrastructure for data collection and processing, development and implementation of machine learning algorithms, and training of agricultural enterprises' personnel.

► Results

The introduction of AI in the agricultural sector opens up new horizons for improving economic efficiency, which is manifested in a number of key aspects. AI enables accurate assessment and monitoring of agricultural land. The use of algorithms to analyse data from satellites and sensors allows farmers to determine the need for fertilizers, irrigation and other resources, which leads to lower input costs and higher yields. Machine learning technologies allow to analyse which crops are best suited to specific growing conditions, which optimises crop rotations and improves overall productivity. By predicting the best time for sowing and harvesting, farmers can increase their output.

In addition, AI helps to optimise water and fertilizer use through precise irrigation and nutrient application. Systems using AI algorithms can automatically adjust the supply of water and fertilizers depending on soil conditions and plant needs, which not only reduces costs but also reduces the negative impact on the environment (Talaviya *et al.*, 2020). Big data analytics and predictive

models can also optimize the processing and storage of products, allowing farmers to better plan production and avoid surpluses, which reduces storage costs and prevents losses.

Another important aspect is increasing resilience to climate change. AI allows farmers to respond more quickly to extreme weather conditions, which helps ensure crop safety and reduce economic risks associated with unstable weather conditions. Studies show that businesses that implement AI technologies have higher profitability. By increasing the efficiency of resource use and improving product quality, farmers can earn more income, which has a positive impact on their competitiveness (Leal Filho *et al.*, 2022).

The introduction of the latest technologies, such as drones for field monitoring, robotic harvesting systems, and automated enterprise management solutions, creates new opportunities for optimising business processes, which not only reduces costs but also increases overall productivity. Thus, the use of AI in agriculture not only increases economic efficiency but also ensures sustainable development of agriculture, reducing its negative impact on the environment (Vrochidou *et al.*, 2022). Innovative technologies are becoming an important tool in addressing the challenges faced by the agricultural sector in the modern world. The environmental aspects of land use play a critical role in ensuring sustainable development, as proper management of natural resources can maintain ecological balance and prevent negative consequences associated with anthropogenic activities. The main environmental issues related to land use include landscape change, land degradation, water management and the impact of urbanisation (Vyshnevskaya *et al.*, 2022; Fedorchuk *et al.*, 2024).

Changing natural landscapes is one of the most obvious problems. Intensive agricultural production, urbanisation, and industrial activities lead to the destruction of natural ecosystems such as forests, marshes, and prairies, which in turn leads to biodiversity loss as many plant and animal species lose their natural habitats (Wang *et al.*, 2021). The use of land for agriculture is often accompanied by the drainage of marshes and deforestation, which has serious consequences for ecosystems. Land degradation is another important problem that arises from the mismanagement of agricultural land. It can manifest itself in the form of erosion, reduced soil fertility, salinity, and pollution. The intensive use of fertilizers and pesticides leads to soil and water pollution, which negatively affects ecosystems and human health (Hossain *et al.*, 2020). Without proper control and remediation, such processes can lead to a significant reduction in land productivity and threaten food security.

Proper water management is critical to ensuring sustainable land use. Improper irrigation and pollution of water sources can lead to water shortages, which can negatively affect agricultural production. Water consumption without consideration of natural resources leads to groundwater depletion, degradation of reservoirs and deterioration of water quality. Due to global climate change affecting precipitation patterns, it is important to develop adaptive strategies for the efficient use of water in agriculture (Srivastava *et al.*, 2021).

Anthropogenic activities, including urbanisation, industry and agriculture, have a significant impact on ecosystems and the environment. Population growth and urban expansion lead to increased demand for land for housing, infrastructure, and agriculture, which leads to competition for resources, degrading environmental quality (Prakash & Verma, 2022). In particular, urbanisation is often accompanied by air and water pollution, which has serious consequences for human health and ecosystems. Biodiversity conservation is an important aspect of environmental management.

Shrinking areas of natural habitats and the use of one-sided agricultural technologies lead to the loss of species diversity. Declining biodiversity reduces the resilience of ecosystems to climate change and other environmental stresses, which threatens the ecological balance and sustainability of agricultural production. Thus, environmental aspects of land use are critical to achieving sustainable development (Li *et al.*, 2020). Effective management of natural resources, biodiversity conservation, and development of adaptive strategies to climate change are key tasks to ensure balanced land use, reduce negative environmental impact, and increase the efficiency of the agricultural sector.

AI is being actively implemented in agriculture to reduce the negative impact on ecosystems, preserve soil and biodiversity, and reduce greenhouse gas emissions. For example, companies such as IBM with its Watson project use AI to analyse data on soil conditions, weather, and water resources. This allows farmers to optimise the use of water and fertilizers, which reduces the likelihood of soil weathering and water pollution. Another example is platforms such as Precision Agriculture, which use machine learning algorithms to predict yields based on historical data and growing conditions. This helps farmers make informed decisions about sowing and harvesting, reducing waste and resource use, which reduces pressure on ecosystems.

The Smart Farming project has developed solutions that use drones and computer vision to identify threatened plant and animal species. This helps agronomists plan crop rotations and use ecological management practices to preserve biodiversity on farms. Using AI to analyse crop rotation data allows farmers to develop more sustainable practices that reduce the need for chemical fertilizers. For example, farmers can receive recommendations on how to change crops in their fields, which helps preserve soil structure and increase fertility. Companies such as Agreena are also using AI to assess the environmental im-

pact of agricultural practices. This allows farmers to better understand how their actions affect CO₂ emissions and other factors contributing to climate change, and to adapt their practices according to the data obtained. Thus, the introduction of AI in agriculture not only increases production efficiency, but also helps to reduce negative environmental impact, conserve biodiversity, and improve soil health (Busse *et al.*, 2021).

In Ukraine, the use of AI in the agricultural sector is growing rapidly, as farmers are actively looking for new solutions to improve production efficiency, optimise costs, and conserve natural resources. Agricultural enterprises are increasingly implementing precision farming technologies based on the analysis of large amounts of data obtained from satellite images, drones, and soil sensors. These technologies allow for detailed monitoring of the condition of fields and plants, determination of moisture levels, soil micronutrient content, forecasting yield potential, and more precise resource management.

One example of how AI is being used is the AgriLab platform, which implements analytics to optimise the use of water, fertilizers and plant protection products, helping to reduce farmers' costs and minimise negative environmental impact. Based on the analysis of long-term data, the platform recommends the most effective irrigation and fertilization schemes, which helps to achieve stable yields even in the face of climate change. In addition, the Ukrainian market actively supports start-ups specialising in the development of machine learning solutions. These start-ups offer innovative tools for yield forecasting, risk analysis, and real-time monitoring of crops. By using AI algorithms, agricultural companies can more accurately predict plant nutrient requirements and detect stressors such as diseases or pests in a timely manner, which helps reduce crop protection costs while ensuring a high level of environmental safety.

Overall, the introduction of AI in Ukraine's agricultural sector not only increases efficiency and productivity, but also contributes to more sustainable development. This is especially important in the context of current challenges, such as soil depletion, climate change, and the effects of war, which make it difficult to maintain high yields without harming ecosystems. AI technologies enable Ukrainian farmers to create more environmentally responsible and cost-effective farming practices that are focused on long-term sustainability and food security. Table 1 shows Ukraine's yields over the past 7 years.

Table 1. Crop yield in Ukraine for 2017-2023, c/ha

Year	2017	2018	2019	2020	2021	2022	2023
Grain and legume crops	42.5	47.4	49.1	42.5	53.9	45.8	55.2
Potato	168	171	155	157	166	174	177
Vegetable crops	208	214	214	207	215	200	209
Sunflower	20.2	23	25.6	20.2	24.6	21.6	24.5

Source: developed by the authors based on State Statistics Service of Ukraine (n.d.)

Different crops show different dynamics, which indicates the need to optimise agronomic practices. In particular, the decline in soybean and rapeseed yields observed in studied years may be the result of environmental factors

or insufficient implementation of innovative technologies, including AI, to manage these crops. This suggests that AI should be more actively used to monitor plant health and adapt agronomic measures to environmental conditions.

At the same time, the high yields of potatoes and fodder sunflower demonstrate the potential for using precision farming technologies, which can lead to increased productivity. For example, the introduction of AI-based systems to predict yields and optimise inputs could significantly improve outcomes for less productive crops. As climate change and environmental conditions directly affect yields, the use of AI-powered analytical tools will help farmers respond to challenges and adapt their strategies more quickly, which will generally contribute to the economic efficiency of the agricultural sector

(Shebanina *et al.*, 2024). To create a forecast table of yields of major crops in Ukraine for the period of 2025-2028, Google Colab AI methods were used to take into account historical data and model various development scenarios. Machine learning was used to analyse past trends and generate forecasts for three main scenarios: optimistic, moderate, and pessimistic. Each scenario considers different levels of annual yield growth or decline depending on expected conditions and possible changes in the industry. Table 2 shows the yield forecasts for different climate scenarios for 2025-2028, c/year.

Table 2. Yield forecasts for different climate scenarios for 2025-2028, c/ha

Year	2025	2026	2027	2028
Optimistic scenario				
Grain and legume crops	58.68	61.45	63.17	66.09
Potato	185.75	192.39	200.46	208.00
Vegetable crops	220.58	228.06	235.06	243.00
Sunflower	26.18	27.29	29.31	30.23
Moderate scenario				
Grain and legume crops	56.19	58.51	59.86	61.25
Potato	180.00	185.06	190.08	195.09
Vegetable crops	215.19	220.06	225.01	230.60
Sunflower	25.19	26.98	26.52	27.29
Pessimistic scenario				
Grain and legume crops	53.77	52.15	51.00	50.86
Potato	170.30	165.29	160.22	155.17
Vegetable crops	210.01	205.67	200.04	195.68
Sunflower	24.03	23.73	23.33	22.00

Source: developed by the authors using Google Colab

The optimistic scenario envisages a significant increase in yields for the major crops, with grain and legume crops reaching 66.09 c/ha by 2028, an increase of 21% compared to the 2023 yield of 55.2 c/ha. Similarly, potato yields are expected to rise to 208.00 c/ha, a 17% increase from 177 c/ha in 2023. Vegetable crop yields are projected to grow by 16% to 243.00 c/ha, and sunflower yields are forecast to reach 30.23 c/ha, a 25% increase from 24.5 c/ha in 2023. The moderate scenario takes a more conservative approach with moderate growth across all crop types. Grain and legume crops are expected to reach 61.25 c/ha by 2028, marking a 10% increase from the 2023 yield. Potato yields are projected to grow by 10% to 195.09 c/ha, while vegetable crops are anticipated to increase by 10% to 230.60 c/ha. Sunflower yields are expected to grow by 10% to 27.29 c/ha by 2028. The pessimistic scenario envisages a decline or slower growth in yields, with grain and legume crops decreasing by 9% to 50.86 c/ha by 2028. Potato yields are expected to fall by 12% to 155.17 c/ha, while vegetable crop yields are anticipated to decrease by 7% to 195.68 c/ha. Sunflower yields are also projected to decrease by 8% to 22.00 c/ha by 2028.

These forecasts provide essential insights for long-term strategic planning, helping the agricultural sector prepare for different scenarios and optimise land use management, ultimately improving the economic efficiency and sustainability of Ukraine's agro-industrial complex. For the effective implementation of AI in land use management in Ukraine's agricultural sector, several

key recommendations should be considered. It is important to ensure proper infrastructure for data collection and processing, which involves investing in modern technologies such as drones, satellite monitoring systems, and Internet of Things sensors for measuring soil and climate parameters. This will allow to collect the necessary data for analysis and decision-making. It is worth focusing on the development and implementation of machine learning algorithms that can process large amounts of data and offer insights into optimising resource use, crop selection, yield forecasting and risk management (Shebanin *et al.*, 2024; Mema *et al.*, 2024).

Agribusinesses should provide training and upskilling of their employees in data and AI, as this will allow them to make the most of new technologies and adapt to the changing environment. The fourth recommendation is to develop partnerships between agribusinesses, research institutions, and technology start-ups, which will allow for joint projects, experience sharing, and innovation (Hafiyeva *et al.*, 2024). It is also important to take into account the environmental aspects of AI implementation, ensuring sustainable development of the agricultural sector and reducing the negative impact on ecosystems. As part of this, agricultural companies should actively implement environmental regulations and standards that would encourage the conservation of natural resources and biodiversity. Finally, state support, in particular in the form of subsidies for the introduction of AI technologies, can significantly contribute to the development of innovations

in the agricultural sector, ensuring the competitiveness of Ukrainian producers in the international market. Implementation of these recommendations can be the key to successful integration of AI into land use management, which in turn will have a positive impact on the productivity and sustainability of Ukraine's agricultural sector.

► Discussion

This section discusses the results of a study on the introduction of AI in the agricultural sector to improve economic efficiency and ensure sustainable development. The findings show that the use of AI allows for accurate monitoring and assessment of land conditions, which enables farmers to use resources more efficiently and optimise fertilizer and irrigation costs. Modern algorithms for processing big data collected by satellites and sensors help farmers better understand the needs of crops and increase their yields.

In particular, predicting the optimal timing of sowing and harvesting makes a significant contribution to economic efficiency, allowing farmers to increase production. Optimising water and fertilizer use through precise irrigation and nutrient application methods also helps to reduce costs and minimise negative environmental impact. These results correlate with the findings of other authors, who emphasise the benefits of precision agriculture technologies in production planning and avoiding surpluses. V. Vidric *et al.* (2023) focused on analysing the economic benefits of precision agriculture. They found that the use of AI in irrigation management could reduce costs and improve crop quality. These results are in line with current research on the efficient use of water and fertilizer, but it was noted that the economic impact could be lower in conditions of poor resource management.

In the study by I. Laktionov *et al.* (2023), the authors analysed in detail the impact of AI on grain yields. The authors focused on the use of drones to monitor crops, which allowed not only to increase productivity but also to reduce losses at the stages of growing and harvesting. The findings are consistent with current research findings, confirming that optimisation technologies contribute to the rational use of resources, increasing the overall productivity of agricultural enterprises. The environmental aspects of land use management are an integral part of the discussion, as biodiversity conservation and proper use of natural resources ensure the sustainability of agriculture. Based on the analysis of Ukrainian agricultural enterprises, it was found that precision farming technologies are already being actively used, which allows for a reduction in the use of chemical fertilizers and minimises the impact on ecosystems. For example, yield prediction platforms allow farmers to make informed decisions about planting crops, reducing costs and ecosystem impact.

To better understand environmental performance, this study applies a yield forecasting model based on climate change scenarios. This approach allows to assess potential threats to production and develop measures to neutralise them. In his work, O.B. Akintuyi (2024) emphasised the importance of environmental aspects of land management. He argued that without proper management of natural resources, even the most advanced technologies can be ineffective. This is in line with current findings that

have pointed out that AI can compensate for governance shortcomings if applied correctly. J.A. Aznar-Sánchez *et al.* (2019) also investigated sustainable land use practices in the context of climate change. They found that farmers who used AI to analyse soil data earned more income by reducing the risk of losses due to extreme weather events. These findings are in line with current findings on increasing climate resilience.

H. Dadashpoor *et al.* (2019) studied the impact of AI on key microeconomic indicators of agricultural enterprises, including profitability and market position. The study showed that enterprises that actively integrated AI into management and forecasting processes significantly improved their competitiveness, especially in international markets. This is in line with current findings, as it confirms the significant contribution of technology to improving the economic stability and competitive advantage of agricultural companies.

For a deeper understanding of the impact of AI on the economic efficiency of the agricultural sector, it is also important to take into account specific aspects such as access to information technology and the level of education of farmers. The adoption of AI technologies can be hampered by insufficient infrastructure in rural areas or limited access to the Internet, which hinders the potential for innovation. C. Feijóo *et al.* (2020) drew attention to the role of government support in the adaptation of AI in the agricultural sector. They believed that without financial support and infrastructure development, the effectiveness of AI adoption would be limited. This differed from the results of the previous survey, which focused more on the need for farmers to organise themselves and to adopt innovative approaches.

An important aspect of the introduction of new technologies in the agricultural sector is the willingness of farmers to adapt to modern management methods, which often requires a change in traditional approaches to farming. The use of AI provides for more accurate planning and forecasting, which can significantly increase the efficiency of crop cultivation and processing costs. However, the success of implementing the latest technologies depends not only on the availability of AI, but also on the ability of farmers to use these tools, interpret data, and adapt management decisions based on the forecasts. W. Leal Filho *et al.* (2022) examined how the impact of AI can affect farmers' total costs in the context of production. They concluded that farmers who use AI to predict product prices can significantly reduce the risks associated with unpredictable market fluctuations. The current research findings show that AI does indeed help reduce costs, but it is important to take into account the limited technical capabilities of small and medium-sized farms, lack of awareness of technology, and the lack of proper infrastructure that would allow for the integration of AI into all stages of production.

Investments in AI in the agricultural sector can have a significant impact on productivity, efficiency, and food safety. M. Ryan (2023) emphasised that, despite the significant initial costs, investments in AI technologies pay off within three years on average, especially if resources are properly managed, which can accelerate this process even in conditions of market volatility. At the same time, J. Azizi (2024) pointed out that the use of AI in the

agricultural sector contributes to increased production, which has a positive impact on food security, especially in regions where there are risks of food shortages. Thus, the introduction of AI not only increases the competitiveness of agricultural enterprises, but also ensures stability and security in the face of climate change, which underscores the importance of farmers' readiness to adapt new approaches to efficient resource management and improve the economic sustainability of the agricultural sector.

In general, it is important to introduce AI in the field of agricultural production, which not only increases economic efficiency but also contributes to the sustainable development of the industry. Research shows that the use of AI technologies enables farmers to use resources rationally, optimise fertilizer and irrigation costs, and increase productivity by accurately monitoring land conditions and predicting the optimal time for sowing and harvesting. In particular, the use of AI-based systems, such as yield forecasting platforms, allows for more efficient production planning, reducing costs and environmental impact.

► Conclusions

The study results confirm that the introduction of AI in the Ukrainian agro-industrial complex can significantly increase the economic efficiency of agricultural production and ensure the sustainable development of the industry. In particular, the use of AI technologies helps to optimise the use of resources, such as fertilizers, water, and pesticides, thanks to the ability to accurately monitor and forecast. The use of predictive models to determine the optimal timing of sowing and harvesting allows farmers to achieve stable production volumes even in the face of climate instability. Projects such as Watson, Precision Agriculture, Smart Farming, Agreea and Agrilab have

become important elements of the analysis. They have demonstrated how innovative solutions based on AI data and algorithms can optimise crop cultivation processes, reduce input costs, and improve crop quality and yield. In particular, the Precision Agriculture and Smart Farming projects use technologies that allow farmers to obtain accurate data on field conditions, predict yields, and control resource consumption, which significantly increases the economic efficiency of production.

The study of crop yields in Ukraine for 2017-2023 analysed their dynamics and considered yield forecasts for different climate scenarios for 2025-2028. The importance of this study is driven by the rapid development of technologies and their ability to significantly increase agricultural productivity, which, in turn, contributes to the country's food security. Based on the results obtained, it can be argued that the introduction of AI in the agricultural sector of Ukraine is not only appropriate, but also necessary to ensure sustainable agricultural development. Given the predictions of climate change and the growing need for food, it is important to continue research in this area to identify new opportunities for increasing productivity. A limitation of the study is the use of historical data, which may not take into account possible abrupt changes in climate and economic factors that affect yields. Further research could focus on integrating more accurate climate models and considering regional specifics to improve the accuracy of forecasts.

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► Conflict of interest

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► **Анотація.** Метою дослідження була оцінка економічної ефективності використання штучного інтелекту (ШІ) для прогнозування екологічних змін у землекористуванні та оптимізації аграрного виробництва. Визначено, що впровадження алгоритмів машинного навчання та аналізу великих даних може значно покращити точність прогнозів щодо стану сільськогосподарських земель, оптимізувати використання ресурсів, зокрема добрив і води, та знизити витрати. Проаналізовано, як застосування ШІ може сприяти більш раціональному вибору культур і плануванню посівів та збирання врожаю, що позитивно впливає на врожайність. Додатково, у дослідженні розглянуто екологічний аспект: використання ШІ дозволяє зменшити негативний вплив на довкілля завдяки точному управлінню ресурсами та зниженню забруднення ґрунтів і водних ресурсів. Робота включала моделювання врожайності для різних кліматичних сценаріїв, що дозволяє прогнозувати можливі результати та розробляти адаптивні стратегії для стабільного розвитку агропромислового комплексу України. Дослідження продемонструвало, що впровадження ШІ в агропромисловий сектор України сприяє підвищенню ефективності землекористування, дозволяючи фермерам оперативніше реагувати на змінні кліматичні умови. За допомогою алгоритмів машинного навчання, зокрема на основі аналізу даних, зібраних із супутникових знімків і сенсорів, можна своєчасно визначати потребу рослин у добривах та воді, що забезпечує раціональне використання ресурсів і знижує виробничі витрати. Моделі прогнозування, застосовані у статті, відображають можливі сценарії врожайності на період 2025-2028 років для різних кліматичних умов, що дозволяє підприємствам краще планувати агротехнічні заходи та мінімізувати ризики. Таким чином, результати дослідження підкреслюють важливість ШІ як інструмента для довгострокового стратегічного планування в аграрному секторі

► **Ключові слова:** прогнозування врожайності; сільське господарство; аналіз даних; інновації; машинне навчання

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