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Establishment of competition in the market of seed and planting material certification services in Ukraine

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► **Abstract.** The quality and varietal purity of seeds is one of the crucial factors in determining the consumer value of any end product. Sowing with high-quality seeds ensures a successful harvest in the future. The purpose of this study was to determine the state (formation and development) of competition in the market for certification of plant variety seeds. The main methods used in the study are statistical analysis, comprehensive assessment, deduction, abstraction, forecasting, historical, and tabular methods. This study investigated the state of competition of subjects of appraisal activity by six objective indicators, analysed their material and technical base, and human potential. The market for seed certification services is a market with limited access and should be characterised as an oligopoly. This market is represented by entities of different forms of ownership and management, it is competitive in determining seed quality and virtually monopolistic in determining varietal properties. Fluctuations in the cost of services are insignificant (15%) and are not currently the main criterion for seed producers when choosing an organisation that conducts seed certification. The present paper was the first to determine the total market capacity in terms of volume and value, and to present possible ways of its growth, which is the practical value of this study. The data presented in this study can be used by other researchers in their scientific work related to this market or agriculture. The findings may also be required by government officials or businesses operating in the market

► **Keywords:** subjects of seed production; public administration; agriculture; varietal and sowing qualities; entrepreneurship

► Introduction

According to Article 15 of the Law of Ukraine No. 411-IV "On Seeds and Planting Material" (2002), as a commodity, seeds are only allowed to enter the market if they have two certificates certifying their varietal and sowing qualities. The right to issue documents is vested in conformity assessment bodies: enterprises, institutions, organisations accredited by the national accreditation body of Ukraine and authorised by the relevant central executive body to carry out conformity assessment activities in the field of seed production (Vinyukova, 2023). Such services are paid for by seed producers, and their cost is included in the cost of seed production, selling price, and ultimately affects the competitiveness of seeds (Shubalyi *et al.*, 2020; Bazaluk *et al.*, 2021).

There are many articles in the scientific literature on scientific approaches, principles, objectives, and the role of plant variety seed certification in Ukraine, etc. It was decided to focus only on those issues that mainly relate

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to the problems of establishing a market for plant variety seed certification services. S. Volodin (2021) proposed the introduction of a digital platform to support the seed production (nursery) system, which could provide expertise on a cluster basis of public-private partnerships, which would increase the quality control of seeds and planting material, improve conformity assessment and certification of products using a consolidated laboratory base. O. Zakharchuk *et al.* (2023) also assessed the current state and prospects of the certified seed market in Ukraine in their study. They described the role of this component, defining it as crucial for food security. The researchers also addressed the existing challenges in finding new opportunities to improve the quality of seeds on the Ukrainian market, as well as the possibility of introducing protectionist measures for the same purpose. Special attention should also be paid to the study by O. Skydan *et al.* (2023). They pointed out the considerable negative impact of the war on Ukraine's agricultural sector and the entire economy. The researchers also proposed some methods of solving the existing problems, but they were described rather superficially, which does not allow them to be used immediately to improve the situation. N. Honcharenko (2022) assessed the existing opportunities to improve the certification procedure for organic production in Ukraine. The scientist noted the role of this component for the development of the country, its application within the framework of international practice, and offered some advice for the future improvement of the market functioning. K. Mazur & O. Zakharchuk (2020) described the existing problems in the commercialisation of the seed market in Ukraine, noting the need to consider the practices of other countries to improve the efficiency of its functioning. The researchers provided a list of public policy areas that could be implemented, although they did so rather superficially.

The purpose of this study was to investigate the specific features of development of the domestic seed certification market in Ukraine, considering its current development trends, and the objectives were to determine the current state and specific features of formation and development of competition in the seed certification market in Ukraine, to clarify the principles of competition in this market; to investigate the capacity and structure of the seed certification market; the impact of competition on the quality and price of services provided by conformity assessment bodies.

▸ Materials and Methods

The information base of the study included data from the Registers of certificates for varietal and sowing qualities of seeds (Registry of seed and/or..., 2023), information from agricultural producers who used the services of seed and planting material certification bodies. The calculations were carried out in MS Excel using statistical research methods. The study analysed the subject composition of conformity assessment bodies in the field of seed production operating in Ukraine, assessing the size of their authorized capital, form of ownership and start of activity; specific features of their activity according to the selected six criteria (number of regions where the conformity assessment body provides services (1), number of seed producers using the services (2), number of crops for which the services are provided (3), number of certificates for sowing quality (4), the total volume of certified grain seeds (5), the number of countries whose seeds are certified (6)); data on the analysis of competitiveness and market capacity in the market for seed sowing quality certification services and the market for seed varietal quality determination services; data on the analysis of the structure of the market for seed and planting material certification services by conformity assessment bodies and types of certification. Furthermore, the legal framework of Ukraine in the field of seed production was investigated, namely, the Law of Ukraine No. 411-IV "On Seeds and Planting Material" (2002), as well as the Law of Ukraine No. 2763-IX "On Amendments to Certain Legislative Acts of Ukraine on Bringing Legislation in the Field of Protection of Rights to Plant Varieties and Seeds and Nurseries into Compliance with the Provisions of European Union Legislation" (2022).

To characterise the market form by the number of participants, the scheme for determining market forms was used and the seed certification services market was classified as an oligopoly with many consumers (452) and several (5) service providers (Aziz *et al.*, 2023). This market is a restricted market, as service providers need to be accredited by the national authority of Ukraine and obtain the authority to carry out conformity assessment activities in the field of seed production, and customers need to be included in the Register of seed and planting material certificates (Registry of seed and planting material certificates, 2023).

The study was based on a systematic approach, which made it possible to combine various aspects of competition in the market of the services under study. The main method used in the study was analysis, which helped to draw the main conclusions of the study based on qualitative and quantitative data available in open sources. The importance of the historical method of research is conditioned by the need to clarify the preconditions for market liberalisation measures in this market. The deduction method helped to explore possible factors influencing the development of competition. The abstraction helped to eliminate factors that had a relatively minor impact on the development of competition in the seed certification market in Ukraine, and thus improve the quality of the model. Forecasting helped to assess the future prospects for the development of this market in the current environment, especially with regard to the war in the country. The statistical method of information processing helped to work on quantitative data characterising competition in the seed certification market.

▸ Results

In 2022, five business entities provided seed certification services in Ukraine, one of which was state-owned and four were private. Thus, it can be argued that in Ukraine, since 2020, there has been competition in the seed certification market. This is conditioned by the fact that there are at least five such structures. State Enterprise (SE) "State Centre for Certification and Expertise of Agricultural Products" was established in 2014, is the successor of the State Seed Inspectorate, which provided services for determining the sowing qualities of seeds for more than fifty years, its branches worked in all district centres, conducting a comprehensive analysis of all seeds sown on Ukrainian

fields, the other four institutions are privately owned and established as limited liability companies during 2016-2019 (Official website of the State Enterprise..., n.d.).

Legislatively, the right to conduct varietal control of the "pre-basic and basic seeds" categories belonged exclusively to the State Enterprise "State Centre for Certification and Expertise of Agricultural Products", i.e., competition was possible only in the market for varietal control of certified seeds. Full competition is present in the market of seed quality assessment services, as all five conformity assessment bodies are entitled to provide services and issue certificates certifying seed quality. On 10.06.2023, the Law of Ukraine No. 2763-IX dated 16.11.2022 (Law of Ukraine..., 2022) came into force, which lifted restrictions on monopoly actions of the State Enterprise "State Centre for Certification and Examination of Agricultural Products" in relation to varietal seed control of seeds of the additional and basic categories.

The level of competition in the market of seed quality assessment services can be described in Table 1. Data for 2022 was used for the analysis. The SE "State Centre for Certification and Examination of Agricultural Products" is currently the most competitive player in the market by all indicators presented in Table 1.

Table 1. Characteristics of the activities of conformity assessment bodies by key parameters in 2022

	Conformity assessment body	Number of regions in which the conformity assessment body provides services	Number of subjects seed producers using the services	Number of crops for which services were provided	Number of certificates issued for sowing quality	Total volume of certified grain seeds, thousand tonnes	Number of countries of origin whose seeds are certified
1	State Enterprise "State Centre for Certification and Expertise of Agricultural Products"	24	361	109	14,560	91.15	37
2	AGROCERT LLC	20	88	60	7,416	7.48	36
3	AGROLABTEST LLC	2	6	10	942	088	13
4	NOVACERT LLC	6	8	7	211	0.42	8
5	VELES-SEEDS LLC	7	19	19	851	8.04	17
	Total	24	452	121	23,980	107.97	47

Note: to avoid double counting, the real value is presented here, not the sum
Source: compiled by the authors of this study based on the Registry of seed and/or planting material certificates (2023)

AGROLABTEST LLC focuses on certification of seeds of varieties, hybrids, and parental components of foreign selection, mainly sunflower and maize, and serves a small number of seed producers, including Limagrain Ukraine LLC, G & Seeds LLC, Agral Agro LLC (Registry of seed and/or..., 2023). In the two years of its presence on the market, it has not expanded the base of service providers. This entity is created to serve concretely identified customers. VELES-SEEDS LLC and NOVACERT LLC started operations only in mid-2021, and therefore it is too early to discuss their impact on the market. One of the main actors in the seed certification market is AGROCERT LLC: it works with every fifth seed producer, operates in almost all regions, and the volume of grain seeds that have received quality certificates is 7.9% of the total amount (Registry of seed and/or..., 2023). As Table 1 suggests, the demand for seed certification services in 2022 was formed by 452 seed producers, including 414 seed producers, and the remaining 38 seed distributors.

The cost of certification services in the field of seed production by state-owned conformity assessment bodies is determined following the legislation and according to the approved rates. Payment for services provided by private conformity assessment bodies is made according to contracts. The study of the cost of certification of sowing qualities of seeds of spiked cereals as of January 2022 (the deadline for updating information on official state sources) found that the cost of this service at the State Enterprise "State Centre for Certification and Expertise of Agricultural Products" is the highest – UAH 1,578.60 per batch of seeds weighing no more than 25 tonnes, and the cost does not depend on the batch size. The analysis of the costing of services was possible only for the state-owned enterprise (Table 2). This relates to the fact that the State Centre for Certification and Expertise of Agricultural Products is the largest, and therefore information on it is available on the Internet, while other companies are not. This calculation raises many questions about the cost of individual works, specifically, the amount of profit is not separated out, but is found in the value of concrete works. The largest share is accounted for by the costs of registration and issuing certificates (almost 25%). It can be assumed that the calculation includes sending one copy of the certificates to consumers, seed producers, by Nova Post with targeted delivery.

Table 2. Calculation of the cost of the service for determining the sowing qualities of seeds of cereal crops in the State Enterprise "State Centre for Certification and Expertise of Agricultural Products" as of January 2022

Service	Cost, UAH	%
1. Sampling and labelling of the seed lot	234.00	14.8
2. Filling in the work log	42.80	2.7

Table 2, Continued

Service	Cost, UAH	%
3. Taking an average sample of the weights	42.80	2.7
4. Analysis of purity weights	129.60	8.2
5. Determination of the thousand-kernel-weight	158.00	10.0
6. Determination of seed moisture content	144.00	9.1
7. Determination of pest infestation	48.60	3.2
8. Preparation of thermostats, bedding, filter paper, sowing seeds	68.00	4.3
9. Determination of seed germination energy	68.00	4.3
10. Determining seed germination	52.00	3.3
11. Analysis of the sample residue for the presence of cultural impurities, quarantine objects, difficult to separate weeds	135.60	8.6
12. Drafting the results (test report)	62.40	3.9
13. Registration and issuance of the certificate	392.80	24.9
Cost of 1 service for seed certification for sowing quality	**1,578.60**	**100.0**

Source: calculated by the authors of this study based on data from the Registry of seed and/or planting material certificates (2023)

To analyse the competitiveness of conformity assessment bodies in terms of the availability of material and technical facilities and qualified personnel, data from the Register of Conformity Assessment Bodies (Registry of seed and/or..., 2023) were used. The highest indicator is in the State Enterprise "State Centre for Certification and Examination of Agricultural Products": accredited laboratories in Kyiv and 11 regional centres, total number of qualified staff – 184 people. AGROCERT LLC has a testing laboratory in Dnipro and two departments in Kyiv and Poltava. Furthermore, it has concluded cooperation agreements with 6 legal entities that have an accreditation certificate and employs 49 specialists. The other conformity assessment bodies own only one accredited laboratory with the number of specialists from 7 to 10 people and have concluded agreements with testing laboratories: 2 agreements with AGROLABTEST LLC and 3 agreements with WELLS-SEEDS LLC and NOVACERT LLC. The powerful material and technical base and the availability of a sizeable number of staff of the SE "State Centre for Certification and Expertise of Agricultural Products" is the main competitive advantage of this institution in terms of geographical coverage of seed producers and the possibility of establishing their close cooperation. Therewith, this indicator has a substantial impact on the growth of service prices. The minimal number of in-house laboratories and staff of the three latter conformity assessment bodies will not allow them to substantially expand their services and create serious competition in the market for seed certification of plant varieties.

An analysis of the impact of military operations on competition showed that the total market for seed certification services for sowing quality considerably decreased: in physical terms, it fell by 29%, or the number of certificates issued was 9,697. The largest reductions in service provision were made by the SE "State Centre for Certification and Expertise of Agricultural Products" – 6,186 services (30%), and AGROCERT LLC – 4,149 services (36%). VELES-SEEDS LLC increased its services, with a 284% growth; the territory where this company operates was not in the combat zone, the company is just entering the market, is mobile, rake part in tender procurement, and has a flexible system of service costs. The company's overall market share is only 3%, but 2022 was a year of significant growth in service provision. Data on the level of competition and the capacity of the seed certification market is presented in Table 3.

Table 3. Level of specificity and capacity of the seed certification services market in 2022

	Conformity assessment body	Rating	Market for seed quality certification services			Market for seed varietal quality determination services	
			Number of certificates issued, pieces	Cost of 1 certificate, UAH	Total cost, thousand UAH	Number of certificates issued, pieces	Total cost, thousand UAH
1	State Enterprise "State Centre for Certification and Expertise of Agricultural Products"	IV	14,560	1,578.60	22,984.4	5,997	11,550
2	AGROCERT LLC	II	7,416	1,380.00	10,234.1		
3	AGROLABTEST LLC	I	942	1,270.80	1,197.1		
4	NOVACERT LLC	II	211	1,380.00	291.2		
5	VELES-SEEDS LLC	III	851	1,340.40	1,140.7		
	Total		***23,980***		35,847.5	5,997	11,550

Source: calculated by the authors of this study based on data from the Registry of seed and/or planting material certificates (2023)

The most competitive price is the cost of the service provided by AGROLABTEST LLC – UAH 1,270.80, or UAH 307.80 less, AGROLABTEST LLC – UAH 1,270.80, NOVACERT LLC – UAH 1,380, and VELES-SEEDS LLC – UAH 1,340.40. The State Centre for Certification and Expertise of Agricultural Products has a fixed price and does not take part in open tenders for work. They are announced by budgetary institutions. AGROLABTEST LLC and VELES-SEEDS LLC take part in tenders and receive significant price discounts for large order volumes. The total current capacity of the services market (calculated through demand) in 2022 was UAH 47.4 million, including certification of seed quality – UAH 35.8 million and varietal quality – UAH 11.55 million, or 75% and 25%, respectively. Thus, SE "State Centre for Certification and Expertise of Agricultural Products" is a monopolist in the market of varietal properties determination services and has a 64.4% share in the market of sowing qualities determination, AGROCERT LLC – 28.5%, the other three conformity assessment bodies have 7.1% of the market. Such data is generally negative for the market, given that a market monopoly generally leads to a lack of competition and, consequently, to its less efficient functioning. Therefore, the government's goal should be to increase the role of private enterprises in the market to improve the situation in terms of competition.

▸ Discussion

M.K. Misra *et al.* (2023) thoroughly covered the role of seed certification in ensuring product quality, noting that seed certification is a process that ensures the preservation of the genetic identity and purity of plant varieties during seed production and propagation, and is based on regulatory standards and procedures applied at different stages of seed production. Therewith, seeds labelled as "certified" meet the specified quality standards, which is confirmed by a certificate issued by the state conformity assessment body. Such certificates should be issued fairly and without unnecessary complications, so as not to create obstacles to the economic development of farmers. According to the scientists, in the US, seed certification was established by the US Federal Seed Act of 1940, and standards were added in 1969 by the Association of Official Seed Certification Agencies (AOSCA) (Federal Seed Act, 1940); the local Federal Seed Act regulates the transportation of seeds between states and requires truthful labelling, and seed companies use national certification standards following this law. In European countries, varieties must be listed in the official catalogue with completed test results for distinctiveness, uniformity, and stability, and value for cultivation and use. In other words, in these countries, the certification process is essential at the state level: it receives a lot of attention from both policy makers and scientists (Loizou *et al.*, 2019). In terms of who plays the main role in the certification process, it is worth noting that in the US it is companies, while in Europe the state plays a relatively higher role. In Ukraine, as noted above, the role of the state institution is more important, and this is a significant difference from highly developed countries. It should be assumed that to ensure a more efficient functioning of the seed certification market, the government should aim to increase competition in the market, specifically by reducing its presence: although it may indeed provide more efficient conditions for companies (considering the economic situation in the country, including the war), this process has its drawbacks, which are particularly evident in the long run (Proskurnina, 2019).

A. Nandi *et al.* (2022) assessed the role of seed certification and re-testing and the development of new varieties and crops in the context of climate change. Scientists have emphasised the need to assess the viability of crop seeds in different locations to ensure their quality and optimal plant health. The current expiry dates were determined based on current climate conditions, but due to rapid climate change, it is likely that other standards will need to be introduced. They also addressed the importance of proper seed storage and avoiding specific conditions of relative humidity and temperature.

U. Joshi & R. Singh (2020) also assessed the features of seed certification. They described seed certification as a vital process in seed production, ensuring that farmers have access to high quality seed to achieve high yields. They conducted their research based on data from India, where the law on this procedure was adopted in 1966 and makes provision for management checks, field examinations, mass inspections, and testing of control plots, which is the key to a prominent level of seed purity and health. Ukrainian seed quality testing companies should pay attention to the procedures carried out and described in the study, so that they can use them in the future within the framework of their own inspections.

M.A. Indrianti *et al.* (2021) described the rice seed certification process at the Seed Certification Supervision Centre in Gorontalo Province, Indonesia. The scientists noted that this process involves several stages: application, authentication of the source, inspection of the field and sowing conditions, isolation of plants and harvesting tools, seed sampling, laboratory quality tests and, finally, issuance of certificates and labels for food plant seeds. However, there are cases of refusal to issue a certificate if the seeds have a high moisture content or poor physical condition. This was also mentioned by P. Schreinemachers *et al.* (2021). This confirms the importance of strict quality control in the certification process to ensure that farmers receive high-quality rice seeds for sowing and further food production, which should be relevant for Ukraine as well.

M. Baglan *et al.* (2020) assessed the role of seed certification implementation using data from Kazakhstan. The scientists noted that ensuring food security is a key component for developing countries, specifically for those characterised by a transitional phase of economic development, which is the case in Ukraine. They believe that the introduction of seed certification will go a long way towards ensuring the production of high-quality products in the country. According to their data, farmers who use certified seeds are 10.3% more efficient, and to motivate them to do so, scientists recommend implementing policies aimed at improving education, providing easier access to credit and empowering farmers to increase their incomes, which was also mentioned by K. Kuhlmann & B. Dey (2021) and S.I. Hlatshwayo *et al.* (2021). In general, all the information received should be relevant for Ukraine, considering certain common features of development with Kazakhstan. By intensifying the seed certification process, the quality of products is improved. However, the implementation of

a clear policy in this area is complicated by the fact that the country is at war, when all efforts are aimed at protecting the territorial integrity and ensuring the stable functioning of the economy and social sphere.

Thus, the situation with seed certification in the domestic market of Ukraine has its own specific features: the existing but low level of competition, its significant monopolisation, the adverse impact of the war, etc. However, to improve the situation, the state could introduce monitoring of the market situation, including competition. Changes in the level of competition in the market should be assessed, and in case of deterioration (increased influence of state institutions), appropriate regulatory actions should be taken. The growth of private seed certification bodies should be promoted to increase competition and provide farmers with more opportunities. It is also important to prevent conflicts between representatives of agricultural enterprises and conformity assessment bodies. This government policy will considerably increase the efficiency of the seed certification market in Ukraine.

▸ Conclusions

If the quality of service delivery is equal, the competitiveness rating of an institution determines the level of service price: the lowest price is the highest rating and vice versa. As of 2022, AGROLABTEST LLC ranked first, followed by AGROCERT LLC and NOVACERT LLC; VELES-SEEDS LLC ranked third, and the SE "State Centre for Certification and Expertise of Agricultural Products" took the fourth place. The market for seed and planting material certification services is a restricted market. In terms of the number of participants, it should be characterised as an oligopoly. The market for seed certification services is competitive in terms of determining sowing and virtually monopolistic in terms of determining varietal properties, as stipulated by legislation. This market is represented by entities of various forms of ownership and business. New conformity assessment bodies are entering the market, having managed to increase their share of the market during the war. The total market capacity exceeded UAH 47 million, the majority of which (75%) is accounted for by the certification of sowing qualities, and the rest (25%) – by the determination of varietal properties. The market has every reason to grow, as the share of certified cereal seeds ranges from 10-20%, and fruit and vegetable seeds are even lower.

Thus, the seed certification market in Ukraine has undergone considerable transformations, shifting from a monopolistic to a competitive environment. While the state-owned centre is still influential, private entities are making inroads by offering competitive prices and expanding their operations. The market's response to the challenges posed by the outbreak of war underlines its resilience and adaptability. The future development of this market will depend on regulatory changes and the evolution of the competitive environment. The scientific originality of this study is a comprehensive characterisation of conformity assessment bodies from the standpoint of competition in the market, identification of their strengths and weaknesses, and rating of the institutions' competitiveness in terms of the price of services. This study is the first to calculate the real capacity of the market of services and determine its structure, and it is promising for future research to continue assessing the dynamics of the market of seed certification services and analysing its individual representatives. Furthermore, it is key to assess the role of the state in the market and take steps to reduce its presence in the market.

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▸ Conflict of Interest

The authors of this study declare no conflict of interest.

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Становлення конкуренції на ринку послуг з сертифікації насіння та садивного матеріалу в Україні

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▸ **Анотація.** Якість і сортова чистота насіння є одним з найважливіших факторів при формуванні споживчої вартості будь-якого кінцевого продукту. Посів високоякісним насінням забезпечує успішний збір великого врожаю у майбутньому. Метою дослідження було визначити стан (становлення та розвиток) конкуренції на ринку послуг з сертифікації насіння сортів рослин. Основні методи, використані під час роботи – це статистичний аналіз, комплексна оцінка, метод дедукції, абстрагування, прогнозування, історичний та табличний методи. В рамках даної роботи досліджено стан конкуренції суб'єктів оціночної діяльності за шістьма об'єктивними показниками, проведено аналіз їх матеріально-технічної бази та кадрового потенціалу. Ринок послуг із сертифікації насіння відноситься до ринків з обмеженим доступом і його слід характеризувати як олігополію. На даному ринку присутні суб'єкти різних форм власності та господарювання, він є конкурентним із визначення посівних якостей насіння та фактично монопольним при визначенні сортових властивостей. Коливання вартості послуг є незначним (15 %) та фактично на даний момент не є основним критерієм для суб'єктів насінництва при виборі організації, що проводить сертифікацію насіння. Вперше визначено загальну ємність ринку в натуральних та вартісних показниках, показано можливі шляхи його зростання, що становить практичну цінність даної роботи. Дані, наведені в рамках дослідження, можуть бути використані іншими вченими для написання власних робіт, пов'язаних із даним ринком чи сільським господарством. Вони також можуть знадобитися представникам державної влади чи власне підприємствам, що діють на даному ринку

▸ **Ключові слова:** суб'єкти насінництва; державне управління; сільське господарство; сортові та посівні якості; підприємництво

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Adaptation strategies of agriculture to climate change and natural disasters

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► **Abstract.** Climate change and agricultural production are processes characterised by substantial mutual influence. Global warming threatens the productivity of agricultural production and food security on a global scale. The purpose of the study is to develop practical adaptation strategies for the impact of climate change and natural disasters on agroeconomic processes. The study uses general scientific methods of cognition: system analysis and synthesis, concretisation, deduction, generalisation, abstraction, and formalisation. In the course of the study, the main factors of the impact of climate change on the agroeconomic sector of production are identified, preventive measures and measures to level climate risks are systematised. Based on the conducted research, a system of tools is developed as part of the strategy for adapting agriculture to climate change and natural phenomena, and the main approaches to assessing the cost of natural disasters for agroeconomics are recommended. The main measures to optimise the ecological and economic situation in the agronomic sector in the context of global warming and effective measures to prevent large-scale losses are developed. The results obtained can be used to conduct research on the dynamics of economic processes during global climate change, develop an appropriate adaptation strategy at the regional and national levels, and form an integrated approach to assessing the cost of natural disasters

► **Keywords:** potential risks; food security; agriculture; agroclimatic conditions; drought

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▸ Introduction

Climate change and weather conditions substantially affect the development of agricultural production. Many papers by researchers are devoted to the issue of the impact of climate change on the agroeconomics and the development of adaptation strategies to such changes. However, in the light of acute urgency, the problem arose in the context of increasing frequency and strength of natural disasters and anomalies as consequences of the global warming process.

In a study by N. Davydenko *et al.* (2021), L. Malytska & V. Balabukh (2020), it is established that the main negative consequence of global climate dynamics is a decrease in agricultural production productivity. Therewith, B. Basok & Y. Baseiev (2020) argue that a sharp increase in the frequency and severity of natural disasters threatens the functioning of the agricultural sector on the principles of sustainable development, stability, and resource-saving in the long term. Modern researchers S. Ivaniuta *et al.* (2020), I. Krasnova *et al.* (2021) consider the consequences of weather and climate impact on agroeconomics in the context of globalisation processes, and researchers V. Latysheva *et al.* (2021) focus on the risks to the environment.

Researchers M.H. ur Rahman *et al.* (2022) highlighted the features of the modern strategy of adaptation of agroeconomics to climate change in a recent publication, considering the prevention and insurance of risks, maximum levelling of primary and secondary consequences of natural disasters and asset regeneration based on the assessment of the cost of natural disasters.

Modern Ukrainian researchers L. Malynka & I. Morhun (2020) show that, with a high probability, warming can contribute to an increase in the yield of many crops (in particular, winter wheat). Therewith, regional differences play a decisive role. However, excessive and rapid accumulation of heat resources reduces the growing season, initiates premature maturation of some crops, leading to a decrease in yield indicators.

Researchers E.S. Lilyk *et al.* (2021) the paper justify the expediency of using modern satellite data capabilities to identify locations of possible weather and climate anomalies, with the aim of timely development of optimisation measures. Therewith, researchers focus on the defining role of agroeconomic management and hybrid forecasting in the prevention and elimination of negative consequences for agriculture, considering global climate processes.

Notably, in the modern scientific search for solutions in the field of the negative impact of extreme weather events and climate change on agroeconomics, the main attention of researchers is focused on the issue of increasing production productivity. Therewith, there is a shortage of papers that could offer a comprehensive solution for strategic adaptation of the agricultural sector, considering technological, economic, and environmental risk factors. Certain aspects of the development of measures to mitigate the consequences of climate change are identified in the works of Ukrainian researchers V. Kolosovska (2020), O. Pohorielova (2022), however, the current situation requires an in-depth methodological approach and the development of practical measures on the problems of preventive risk management in the agroeconomics from natural disasters and climate change, minimising the consequences of such impact and regeneration measures for potential possible scenarios of consequences.

The purpose of the study was to develop an effective system of management and technical-economic preventive decisions on the impact of climate change and weather and climate disasters on agroeconomics and examine modern approaches to estimating the cost of natural disasters. The paper is aimed at developing a practical adaptation strategy of agroeconomics to climate change.

▸ Materials and Methods

The paper processed scientific literary sources and publications in industry specialised publications, monographs, and conference materials. The theoretical basis of the research consists of scientific publications on the subject under study (Ogada *et al.*, 2020; Liu & Basso, 2020; Dumrul & Kilicarslan, 2017), statistics from official national sources (Official website of the Ukrainian…, n.d.; Official website of the State Institution…, n.d.), the results of independent observations (Anderson, 2020; Chandio, 2020; Jatuporn & Takeuchi, 2023), practical recommendations on the subject (Tonnang *et al.*, 2022; Habib-ur-Rahman *et al.*, 2022; Tsinda *et al.*, 2019), devices for implementing the adaptation strategy in various climatic and economic conditions (Solomon *et al.*, 2021; Fujimori *et al.*, 2021; Lomba *et al.*, 2020) and analytical materials (Tubeuf, 2022; Eckhardt *et al.*, 2019).

The examination of the impact of global climate changes on agroeconomic processes provided for the formation of a system of regularities and features of the object of the study. In particular, the possibilities of optimising the situation and choosing optimal preventive and regenerative solutions using the generalisation method were examined. The method of convergence from abstract to concrete is applied in the context of the transition from general knowledge about the vectors of the negative impact of climate change and extreme weather events on the economy to the essence of consequences for agricultural activities based on which the formation of practical measures for the prevention of destructive consequences and management of ecological and economic risks, and early forecasting, is conducted.

The study also uses methods of system analysis, synthesis, deduction, concretisation, formalisation, and abstraction. In particular, with the help of system analysis, structural connections between the phenomenon's elements are established, and existing approaches to estimating the cost of natural disasters are examined. The synthesis method is used in the study to position the existing system of adaptation to climate change and extreme weather situations in Ukraine, and the management mechanism for risk management. The deduction method is used to highlight the essence of the negative impact of climate dynamics on economic indicators and the ecological state of the agricultural production sector.

Using the general scientific method of abstraction, the concept of a holistic process of monitoring and controlling the parameters of the state of agrocenosis and managing ecological-economic risks arising as a result of direct and indirect consequences of climate change and

natural weather events is formed. The optimal information base of such a process can serve as a basis for developing a system of compensation for losses and effective insurance, early forecasting of extreme situations, and organising a system of emergency response measures.

The concretisation method is used to fix the effectiveness and expediency of urgent preventive measures and regeneration measures within the framework of the adaptive strategy of agroeconomics for climate change and sustainable development and to predict possible negative consequences in short- and long-term time sections. In addition, the method of concretisation in the course of the study was used to identify optimal conditions and solutions for levelling the risks of prolonged consequences for agroecosystems, and adapting the existing agricultural management system to the basic requirements of a sustainable economy and preventing climate change.

The formalisation method was applied during the development of priority vectors for the policy of stabilising the state of agricultural territories in Ukraine amid global climate changes. This method was also instrumental in documenting the outcomes of the study, emphasising its active practical integration into the optimisation of climate risk management for agroeconomic processes.

▸ Results

Agriculture is a key sector of the Ukrainian economy, which ensures an adequate level of food security and raw material reserves, but it is a powerful source of greenhouse gas emissions. Currently, the agronomy industry cannot be classified as highly vulnerable to climate change, but there is an increase in the intensity and frequency of droughts, which may, in the future, lead to desertification in the southern regions of the country and the expansion of the zone of risky agricultural production. With the trend of dehydration in Ukraine's central and northern territories, gross grain production while maintaining the current agricultural technology system may substantially decrease by 20-25% in the coming decades (Malynka & Morhun, 2022).

Climate change is a condition in which the gradual substantial dynamics of the global climate model lead to the phenomenon of instability of temperature indicators, the occurrence of extreme weather conditions, seasonality shifts, and substantial fluctuations in precipitation (Fig. 1). Climate changes have a negative impact on the agricultural sector, and the determining factor is not only the increase in the average annual air temperature, but also the direct consequences of the process – violation of the duration of the growing season, the frequency of frosts, an increase in the likelihood of extreme weather conditions, etc. Elevated temperatures accelerate the growth of plants, and therefore, the content of trace elements in crop tissues decreases due to the slowdown in synthesis processes. In addition, the incidence and pest damage substantially increase, because increased temperature indicators reduce active immunity, which usually blocks the spread of phytopathogens, and also stimulates transpiration processes. Of all the natural disasters, droughts and floods have the most substantial negative impact on agriculture in Ukraine. 83% of the damage caused to the agronomy sector by natural and climatic anomalies is caused by droughts, while both crop and animal husbandry suffer losses (Malynka & Morhun, 2022; Official website of the State Institution…, n.d.).

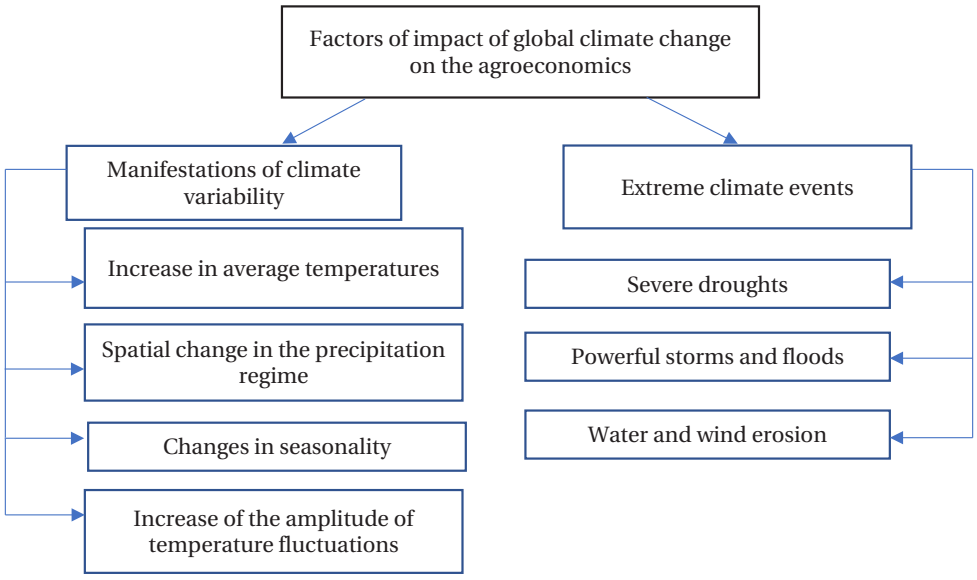

Figure 1. The main consequences of global climate change for agroeconomic processes
Source: compiled by the authors

The factor of climate change and weather anomalies has a substantial impact on the chain of food pricing policy formation, affecting the volume of products produced, the production process and reserves. According to the Ukrainian hydrometeorological centre (Official website of the Ukrainian…, n.d.), since the 2010s, the frequency of natural meteorological phenomena has substantially increased (up to 200 per year). Therewith, statistics show that every 10 years, the number of natural phenomena and natural disasters in Ukraine increases by approximately

4% (Official website of the Ukrainian…, n.d.). They cause soil erosion, erosion processes, flooding, and washing away of crops.

Disruption of metabolic processes, minimisation of humus reserves in the soil cover and changes in the rate of its mineralisation are direct consequences of substantial climate changes. According to the results of long-term statistics (Official website of the State Institution…, n.d.), every five years there is a loss of 0.05% of humus in the soil. In monetary terms, over twenty years, the equivalent amount is about 450 billion UAH. In addition, substantial losses are provoked by salinisation processes, and wind and water erosion phenomena. Loss of yield can lead to an increase in prices for agricultural products and have a destructive impact on the agricultural sector and food security on a global scale.

The phenomenon of global warming causes changes in the agroclimatic conditions of agricultural production productivity in Ukraine. Since the beginning of the 2000s, there has been a substantial increase in average temperatures in winter, an increase in the heat supply of the growing season, a change in the duration of seasons and the development of natural processes, a decrease in soil fertility, and an increase in the frequency of extreme events (Kolosovska, 2020). According to the results of long-term statistical observations, for the period from 2010 to 2022 in Ukraine, the number of days a year with high daytime air temperatures almost doubled (Official website of the Ukrainian…, n.d.). This fact explains the tendency to increase the duration of active vegetation of crops, which can cause premature maturation and a decrease in the yield of agricultural plants. In addition, climate change provokes the dynamics of another important agroclimatic indicator – the humidification regime. In 2021-2023, Ukraine is experiencing an increase in the frequency of droughts, uneven precipitation during the growing season, and a reduction in precipitation in winter. Accordingly, the regional specifics of water supply form the distribution areas of agricultural crops, which are substantially narrowed for moisture-loving agricultural plants. As of today, industrial cultivation of some traditional crops (corn, sunflower) in the southern steppe region is becoming economically impractical.

One of the consequences of global climate change is a shift in habitual seasonality. As a result of these dynamics, uncharacteristic temperature contrasts occur in regions where such a phenomenon has not previously been observed (Official website of the Ukrainian…, n.d.). The damage caused by temperature stress can be expressed in cellular abnormalities and problems with seed germination, improper adaptability of crops, and loss of yield indicators.

Among other negative consequences of climate change for the agroeconomics, it is worth highlighting the most substantial: reduced grain quality; violation of the vegetation regime of crops due to intense droughts; the problem of soil moisture in the southern regions of Ukraine; intensification of humus decomposition; violation of the process of complete vernalisation of grain crops; an increase in the number of pests due to favourable wintering conditions; the spread of water and wind erosion phenomena; increased risk of freezing of winter crops due to lack of proper snow cover. Solving a number of problems caused by climate variability and climate extremes requires consistency of management policies, agronomic programmes and practical means of their implementation. In order to implement an effective adaptation strategy, synergy of efforts in all aspects is necessary, which provides for comprehensive risk management and the introduction of methods for improving the sustainability of agricultural systems in the short, medium, and long term (Rahman, *et al.*, 2022; Ogada *et al.*, 2020). Therewith, it is important to consider the limitations of individual vectors of adaptation under existing economic conditions, and substantial positive dynamics can often be achieved only in the context of radical changes in the existing agronomy sector. The adaptation strategy can be effectively implemented only considering local specifics, in the conditions of creating a system for predicting climate extremes, developing preventive and regenerative measures, and developing opportunities in the field of risk management.

Modern approaches to estimating the cost of natural disasters for agroeconomics separate direct physical damage from indirect production costs and additional or secondary consequences. These types of losses are interrelated and can become material or non-material, and the categorisation of potential losses supports the distinction between direct, indirect and secondary losses as a result of natural disasters (Kolosovska, 2020). Direct losses occur as damage as a result of a weather and climate catastrophe. Therewith, they can cause indirect losses, which in turn lead to secondary consequences. The latter have a prolonged impact and are usually felt throughout the entire recovery stage. In addition, their characteristic feature is the ability to form prerequisites for further vulnerability. In particular, a decrease in production and employment opportunities due to direct and indirect losses in the agricultural sector can provoke secondary losses due to a reduction in production capacity, a decrease in demand and investment volumes, etc.

The assessment of the cost of the impact of natural disasters in the field of agroeconomics is influenced by the size and structure of the socio-economic background and the nature of the natural disaster. Therewith, it is necessary to consider the fact that a small and poorly diversified agricultural economy with spatially concentrated production assets is extremely vulnerable to natural disasters that occur in synergy with economic shocks (Tonnang *et al.*, 2022). Notably, if direct losses can be minimised, then indirect and secondary effects can also be levelled or reduced.

The trend of climate change makes it necessary to revise traditional plant protection technologies in favour of increasing the frequency of treatment with plant protection products, adapting the timing of agricultural manipulations. Therefore, it is necessary to avoid increasing the concentrations of chemical treatment of crops because this can lead to pathogen resistance, the need to develop new means of protection and an increase in the cost of agricultural products produced. The substantial impact of climate change on the agricultural economy requires substantial efforts aimed at minimising the impact, levelling negative consequences, and forecasting in a timely manner. Such goals can be achieved by developing an optimal adaptation strategy (Fig. 2).

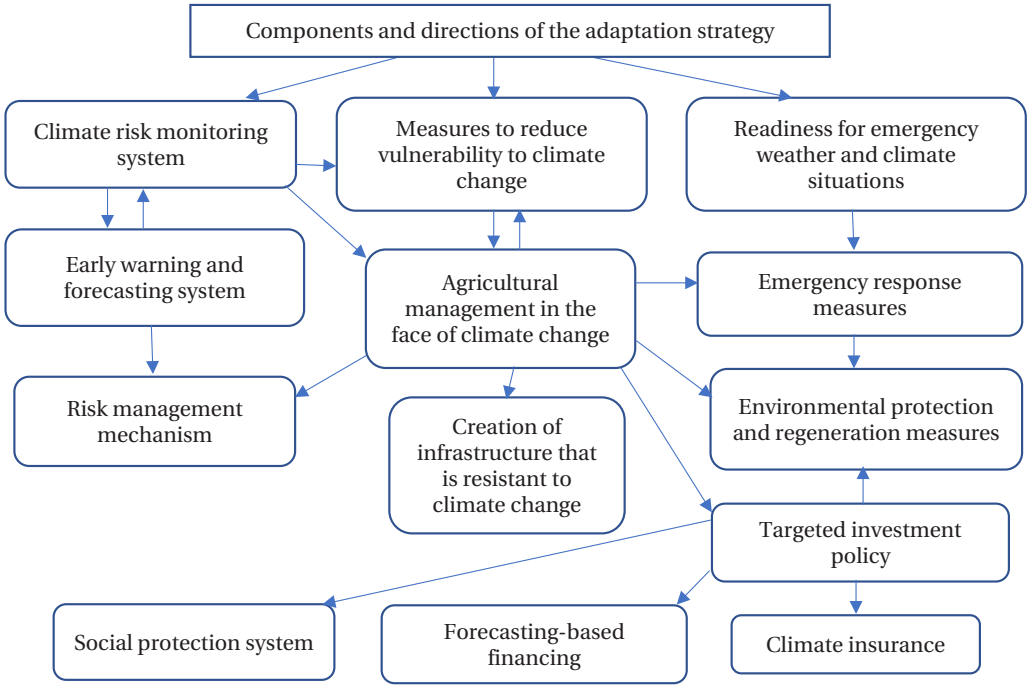

Figure 2. Measures and tools to minimise the impact of climate change on the agroeconomics
Source: compiled by the authors

It is evident that the introduction of climate-resistant technologies and strategies for agro-industrial production is relevant today, which can not only mitigate the negative impact of climate change on the functioning of soil cover, water regime and other environmental parameters but also increase the production level under challenging conditions. It is notable that climate change affects the economic sustainability of the agricultural sector both directly and indirectly. Adaptation strategies should include, first of all, optimal dynamic planning of agricultural activities, considering the risks that arise for farmers due to climate change. In addition, selective measures, improving the irrigation system and ensuring soil moisture and biotic environmental strategies are integral (Lilyk *et al.*, 2021).

In some countries, rainwater collection technology is successfully used, which involves retaining excess moisture during the season of excessive precipitation (for example, using dams) and reusing it during the drought season (Tsinda *et al.*, 2019; Solomon *et al.*, 2021). Therewith, this technology allows effectively dealing with the phenomena of erosion. Economical tillage technologies are an integral part of adapting the agricultural economy to climate change, increasing carbon uptake, optimising infiltration processes and reducing soil erosion (Malynka & Morhun, 2022; Pohorielova, 2022). The effectiveness of measures to predict and minimise the risks associated with climate change depends, to a large extent, on the level of awareness of farmers and their motivation regarding the feasibility of strategic adaptation (Lomba *et al.*, 2020; Kharb *et al.*, 2022). Due to the lack of effective early forecasting, agricultural production declines and crop failures are becoming commonplace in the face of climate change.

Adaptive agricultural production opens up the possibility of optimising the degraded state of resources since it involves minimising the destruction of soil cover, preserving biodiversity, replacing synthetic means of protection and nutrition with organic ones, and increasing the volume of terrestrial carbon uptake (Fróna *et al.*, 2021; Malhi *et al.*, 2021). It is also necessary to select varieties of crops that would have increased adaptive capabilities to climate fluctuations and be resistant to diseases and pests (Malytska & Balabukh, 2020; Alleyne & Jones, 2022).

Integrated nutrient management strategies, active use of breeding and biotechnologies, and effective pest control can provide optimal prerequisites for sustainable development of the agro-industrial complex even in the face of climate change. In addition, using the capabilities of modern simulation and decision-making systems, a global positioning system, remote sensing, and innovative approaches to forecasting allows developing optimal effective strategies for adapting to negative weather and climate trends and natural disasters.

To adapt to climate change and offset the negative consequences, the concept of implementing the state policy in the field of climate change until 2030 is in force in Ukraine, which provides for reducing anthropogenic emissions, stimulating the processes of greenhouse gas absorption, and also forms an algorithm for the gradual transition to a low-carbon strategy for the country's development (Malynka & Morhun, 2022). Therewith, the main task of institutional support remains to regulate the priority of tasks related to the impact of climate change on the agronomy sector while maintaining a balanced development of all components of the agricultural production system. It is also necessary to take appropriate structural measures regarding the design and location of buildings and other infrastructure elements to minimise the possible consequences of natural disasters. In addition, the adaptation strategy should consider the challenges and opportunities that arise from the growing trends towards

globalisation, which has expanded opportunities for risk diversification.

It is advisable to encourage the private sector of the agricultural economy to raise awareness of the risks associated with natural disasters and climate change and to implement appropriate risk management tools. Together, the proposed measures as part of agricultural management in the context of climate change will reduce the level of vulnerability of the industry to weather and climate anomalies, stimulate economic growth and development, implement deregulation of investments in agriculture, use forecasting opportunities to reduce the impact of climate variability and implement effective financial risk management mechanisms.

▸ Discussion

Ukraine is currently one of the twenty countries in the world that emit the most greenhouse gases into the atmosphere (Kolosovska, 2020). This fact indicates the inevitability of substantial negative consequences of climate change for the region. The primary result of global warming for the agricultural economy is a reduction in agricultural production, primarily due to a decrease in yield indicators. Overall, climate change has mixed impacts on agriculture, manifesting itself in both negative and positive trends. To date, researchers have recorded an increase in average temperature values in Ukraine by 1-1.5°C, and a trend of further warming characterises the situation (Official website of the Ukrainian…, n.d.).

Researchers R. Anderson *et al.* (2020) note that the most dangerous consequences of climate change are not global warming itself, but the phenomena caused by it: heat, drought, storms, hurricanes, and other natural disasters. Currently, there is an increase in the frequency of abnormal weather conditions. The actual majority of agricultural areas are currently in the zone of risky farming. The daily temperature regime has undergone sharp changes, which is often characterised today by substantial contrasts of night and day temperatures. Researchers claim that adaptive crop systems responsible for tolerance to stressful phenomena do not cope with the task of levelling the ranges of differences, which substantially disrupts plant development. It is hard to disagree with researchers.

In general, among abiotic stresses, M.H. ur Rahman *et al.* (2022), A.A. Chandio *et al.* (2020), M. Habib-ur-Rahman *et al.* (2022) highlight heat stress as the most threatening factor for the sustainable development of agronomy since it can cause changes in the modulation of gene expression, metabolic disorders, activation of oxidative stress, and even destruction of the foundations of genetic structural material. Researchers have proven that the degree of influence of heat stress on the quality of grain crops depends on the variety of crop, but the negativism of the trend persists regardless of agricultural characteristics. In view of the above, the researchers consider it appropriate to include in the strategy of adapting the agroeconomics to climate change such measures as, for example, the use of organic antioxidants and osmoprotectors. In this study, identical recommendations are formed – the use of maximum opportunities for preventive safe agricultural measures.

Modern researchers S. Fujimori *et al.* (2021), D. Eckhardt *et al.* (2019) noted that the degree of economic damage, the indirect effect caused by a natural disaster, depends on the degree of interdependence of economic and production factors. Researchers give an example that as a result of a natural disaster, in the future, agriculture may face the loss of energy supply and communication infrastructure or labour, even if production resources are not damaged. Therewith, research results Y. Dumrul & Z. Kilicarslan (2017) indicate that when assessing the impact of the consequences of disasters in the long term, attention is focused on production volumes and labour productivity. However, given the possibility of severe damage to non-current assets and other resources as a result of a natural disaster, productivity can be substantially reduced due to the disruption of markets and infrastructure. Researchers note that all major types of natural disasters, including drought, can disrupt long-term investment plans. Such conclusions are synergistic with the results of this study.

Researchers Y. Liu *et al.* (2020) are convinced that the damage can be covered by insurance policies. However, it is difficult to agree with researchers, because even in this case, alternative losses are real, and certain types of destroyed assets cannot be replaced. In the long run, the risks associated with natural disasters and natural disasters can contribute to economic instability, limiting investment opportunities. The use of innovative agroecological management systems by farmers, along with traditional management paradigms and the latest opportunities for biodiversification and management of soil and water resources, open up new opportunities for levelling the negative effects of climate change. Climate-resistant technologies provide optimisation of the state of the natural environment involved in the agricultural sector, increase carbon absorption, and minimise erosion phenomena, which in synergy allows forming a sustainable production system in agriculture and neutralises the threat of a food crisis. Therewith, it is considered appropriate to classify the main adaptation methods by resource-saving factor, variability of agricultural technologies, and socio-economic factors. In addition, according to researchers C. Jatuporn & K. Takeuchi (2023), the priority areas in forming an adaptation strategy should be market integration and capacity development, and such conclusions are similar to the results of this study.

Considering the results of the studies, it can be concluded that reducing the level of risks caused by climate change can be achieved in the conditions of developing an optimal adaptation strategy, which should provide for the main primary implementation vectors, including: increasing the resistance of ecological and economic systems; developing an adaptation policy mechanism from regional to national level; balanced resource consumption and environmental management; implementing an effective system for monitoring and forecasting natural and climate dynamics; engaging in cross-border projects on adaptation to climate change; strengthening the institutional capacity to implement state policies to prevent climate change and mitigate negative consequences; increasing the neutralisation and absorption of greenhouse gases through specific land-use measures; implementing medium-term defined low-carbon development strategies and other international commitments (García-León *et al.*, 2021).

In addition, the adaptive concept of reducing the negative impact of global climatic processes on crop

production should provide for the priority of species and varieties of agricultural crops with a short growing season, expanding the diversity of agricultural crops to strengthen the resistance of the agroecosystem to external negative influences; introducing an effective irrigation system; breeding productive varieties with increased drought resistance; effective agronomic monitoring; and managing the optimisation of the nutrient regime and metabolism of crops and the use of insurance opportunities in agricultural production (Basok & Baseiev, 2020; Van Huong *et al.*, 2021; Sangha *et al.*, 2020).

The impact of climate change and natural disasters on factors of long-term economic growth shows an acute consequence shortage of financial resources, which can reduce the pace of agroeconomic development. In this regard, researchers A. Lomba *et al.* (2020) emphasise the need to disclose the risks associated with dangerous weather and climate phenomena while highlighting the most important among the prerequisites – substantial opportunity costs associated with diverting resources to recovery from natural disasters. Researchers argue that natural and climate disasters negatively impact both the short and long term, and the agroeconomic situation today refutes the established belief in minimising the vulnerability of agriculture to natural disasters as the economy grows. Thus, natural disasters create negative trends for both short-and long-term prospects for the development of the agricultural economy. It is necessary to thoroughly assess the risks to agricultural production associated with natural hazards and include the results of such an assessment in the development strategy and policy of Agricultural Management. It is essential to be aware of the differences between potential short-term and long-term impacts, and possible trade-offs between them, considering the totality of relationships (Eckhardt *et al.*, 2019; Yu, & Wei, 2022). After all, agricultural production, from the point of view of economic feasibility, requires strategic adaptation to climate hazards to minimise risks.

To promote sustainable agronomy, both the individual perception of preferences and the introduction of functional methods of market exchange are necessary to ensure the resource base and economic motivation of farmers and stimulate the development of Industry alliances. Climate-smart agriculture involves adapting the agricultural sector to climate change by rationalising the use of resources, implementing effective management, and applying innovative low-carbon technologies and agronomic strategies. An integrated approach to the prevention and levelling of climatic consequences, and an effective assessment of the cost of natural disasters will create optimal prerequisites for the formation of a practical concept of adaptation of agroeconomics to the negative dynamics of weather and climatic conditions.

▸ Conclusions

Climate changes cause destructive processes in the agroeconomics, substantially affecting the level of agricultural production through negative trends in crop yields, reducing the intensity of agriculture, reducing acreage, minimising investment in the agro-industrial complex. As a result of the study, it was possible to analyse the main aspects of the impact of climate change and natural weather disasters on agricultural production in the example of natural conditions in Ukraine. It was determined that the potential impact will lead to substantial negative consequences on a local, regional, and global scale, in the form of reduced yields and product quality, and even a food crisis. The manifestations and secondary consequences of climate change on agroeconomic processes are systematised. There is a threat of a decrease in agroeconomic productivity indicators under the influence of weather and climate disasters. Mechanisms for assessing the cost of natural disasters were analysed.

As a result, priority measures and tools in the structure of the adaptation strategy for minimising the impact of climate change and natural disasters on the agricultural economy were identified. These include adaptive management mechanisms, innovative capabilities of the risk monitoring, forecasting and early warning system, improved emergency response algorithms, social protection, insurance and investment support systems, and measures to increase the sustainability and expansion of dynamic properties of agroeconomic systems.

It is established that only an integrated multidimensional approach to the development of a strategy for adapting agroeconomics to climate change and weather extremes, with the introduction of innovative monitoring and forecasting capabilities, the use of effective insurance and social protection systems will allow responding promptly to negative trends in agriculture caused by climate factors, preventing a decrease in production opportunities. Therewith, priority should be given to preventive measures, a risk prevention system, and emergency preparedness.

The need to improve existing approaches for effective and reliable assessment of the cost of natural disasters in the examined area was identified. The main prerequisites and factors that contribute to the effective implementation of the risk management system associated with adverse weather and climate trends were also highlighted. Among these factors, the introduction of an early forecasting and crisis management system, the organisation of an economic buffer and insurance for unpredictable weather and climate impacts are notable. Priority vectors of the examination of the impact of climate change on agroeconomic processes and the need to organise and systematise research information were proposed. The importance of further research in applying managerial and technological preventive measures, including modern tools for risk insurance, crisis management, forecasting and adaptive modelling, was emphasised.

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▸ Conflict of Interest

None.

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Адаптаційні стратегії сільського господарства до змін клімату та стихійних природних явищ

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► **Анотація.** Зміна клімату та сільськогосподарське виробництво – процеси, що характеризуються суттєвим взаємним впливом. Глобальне потепління ставить під загрозу продуктивність виробництва агропромислового комплексу та продовольчу безпеку у світовому масштабі. Метою дослідження була розробка практичних адаптаційних стратегій до впливу кліматичних змін та природних стихійних лих на агроекономічні процеси. В дослідженні були використані загальнонаукові методи пізнання: системний аналіз та синтез, конкретизація, дедукція, узагальнення, абстрагування та формалізація. У ході роботи визначено основні фактори впливу кліматичних змін на агроекономічний сектор виробництва, систематизовано превентивні міри та заходи щодо нівелювання кліматичних ризиків. На основі проведеного дослідження, було розроблено систему інструментів в складі стратегії адаптації сільського господарства до змін клімату та стихійних природних явищ, рекомендовано основні підходи до оцінки вартості природних катастроф для агроекономіки. Розроблено основні заходи з оптимізації еколого-економічної ситуації в агрономічному секторі в умовах глобального потепління, а також ефективні міри для запобігання масштабним збиткам. Отримані результати можуть бути використані для проведення досліджень шодо динаміки економічних процесів у період глобальних кліматичних змін, розробки відповідної стратегії адаптації на регіональному та національному рівнях, а також у ході формування комплексного підходу до оцінки вартості природних катастроф

► **Ключові слова:** потенційні ризики; продовольча безпека; сільське господарство; агрокліматичні умови; посуха

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The impact of trade policy and agreements on the development of international trade in Ukraine's agricultural sector

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► **Abstract.** International trade is now one of the main types of international relations, without which it is impossible to imagine the modern functioning of any economy. Thus, it is significant to investigate the impact of various types of government policies and individual agreements on this type of relationship and the very development of countries. The purpose of this study was to show how external activity and trade interact in the agricultural sector in Ukraine. The main methods employed in this study included analysis, forecasting, and abstraction. The study described the role of international trade, specifically in the agricultural sector, considering its significance for the country's economic development. The role of international trade was briefly described from a theoretical standpoint. The study, based on the analysis of statistical data, also showed the impact of trade agreements on the development of foreign trade. In the context of the study of the agricultural economy, it was shown that the gradual growth of Ukrainian agricultural exports, imports, and foreign trade is strongly related to the number of trade agreements concluded. The corresponding equation of dependence of values was constructed and its economic meaning was explained. The role of the sector in general, and specifically in the current martial law environment, was also described. Special attention was paid to Ukraine's agricultural sector, which plays a crucial role in economic development. The role of this sector and the unique characteristics of the industry were substantiated. A strong correlation between the number of trade agreements and the volume of international trade in the agricultural sector of Ukraine was noted through regression analysis, which led to conclusions about the role of trade agreements in the development of international trade in agricultural products. This study brings new knowledge in terms of assessing the role of international trade for the country's development, as well as analysing the current general state of Ukraine's economy

► **Keywords:**: macroeconomics; public policy; management; international relations; development

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▸ Introduction

International trade itself plays a major role in the global economy and generally in society. It is the process of exchanging goods, services, capital, and other resources between countries through the purchase and sale of goods and services between entities located in different countries. The main benefit of this process is that different countries have different resources, competitive advantages, and production capabilities. This leads to the specialisation of countries in the production of certain goods and services. Thus, international trade allows countries to exchange goods and services for mutual benefit and raising overall living standards. As a result, it leads to faster economic growth over time, more efficient division of labour and specialisation (based on existing competitive advantages), access to different goods, etc. All these and other factors contribute to the fact that states are trying to develop free trade relations between them, but there are still reasons to limit them. They are diverse: it can be a desire to protect their own domestic market, the need to preserve their own strategic industries (e.g., agriculture), or to protect the external environment within the country. That is why it is significant to investigate how trade terms, tariffs, and other restrictions affect the development of international trade and the economy.

One of the key components of international trade is trade in agricultural products (Havrylyuk, 2022). This sector includes crop production, animal husbandry, forestry, and fishing. The trade in this type of product is still particularly relevant in Ukraine, which specialises in the production of this product, specifically grain. Thus, sales of agricultural goods account for the bulk of both budget revenues and foreign exchange earnings from abroad. Furthermore, the development of this sector brings significant benefits to the entire country's economy, namely by creating jobs and ensuring food security. Thus, it is important to consider the factors that influence international trade in agricultural products. This study focused on the impact of international trade through tariffs and other restrictions.

Many scholars have analysed international trade generally, and Ukrainian trade specifically. Thus, O. Ilyash *et al.* (2019) assessed changes in Ukraine's export-import commodity flows in international trade as a result of the Russian occupation (before the full-scale invasion). Scientists noted and described the main trends in the country's international trade, primarily related to the geographical reorientation of the country in terms of imports to the countries of the East and exports to the West. U.V. Rosola *et al.* (2023) investigate the impact of the war on Ukraine's economy from the economic standpoint, including in terms of trade. The scientists described the significant adverse consequences that are relevant to the country now, and also made their predictions about how the situation might develop in the future. N. Parkhomenko *et al.* (2022) described Ukraine's considerable export potential in the agricultural sector and emphasised the importance of food safety and state support. For these purposes, scientists have proposed certain components to increase this potential and support it, specifically, by modernising the supporting infrastructure, such as seaports. O. Totska (2022) emphasises the importance of continuous monitoring and forecasting of Ukraine's agricultural exports in the context of its European integration and international trade. The researcher showed the difference in the export potential of different types of Ukrainian agricultural products but did not provide sufficient recommendations to avoid these difficulties. F. Zhang (2020) investigated the analysis of the current situation of agricultural trade between China and Ukraine within the framework of their study. The researcher demonstrated the fact of growing interaction between countries in the context of international economic relations and provided advice on how to further improve them using various methods.

The purpose of the present study was to show how various restrictions in the context of international trade (specifically in agriculture) affect economic development, using evidence from Ukraine. This will not only help to build a more effective international trade policy, but also bring new knowledge in the field of international trade studies.

▸ Materials and Methods

The study assessed the statistical data characterising Ukraine's foreign trade. For this, separate databases were used, namely, the World Bank (Exports of goods..., n.d.; Imports of goods..., n.d.) (to analyse data characterising the country's foreign trade) and the World Trade Organisation (WTO) (RTAs currently in force..., 2023) (to analyse the number of trade agreements concluded by the country). Data on the level of depreciation of the dollar was also used (as the data used was denominated in this currency). For this, the website Calculator.net was used (Inflation calculator..., n.d.). Subsequently, based on these data, a regression model was built to characterise the impact of the number of agreements on international trade and foreign trade in agriculture. First, the volume of Ukraine's foreign trade was determined in dollar terms for 1992-2022 (and 2003-2022, respectively). Subsequently, their value was adjusted for the US dollar inflation rate (to estimate the real data without the impact of currency depreciation). This variable was defined as a dependent variable, while the number of trade agreements established between Ukraine and other countries – as an independent variable. Based on these data, a regression equation was constructed, which in the general case (with one independent variable) has the following form:

$$y = a + bx, \quad (1)$$

where y is the dependent variable (in this case, the volume of foreign trade adjusted for inflation); x is the independent variable (the number of trade agreements concluded).

Thus, the main approach used in this study was a systematic one. This helped to analyse individual factors influencing international trade, assessing it within a single model within which they interact with each other. This increased the efficiency of the analysis of these factors and made the conclusions clearer and more balanced. The method used in the study was analysis. It helped to conclude on the current state of Ukraine's international trade based on known qualitative and quantitative indicators about this phenomenon. The historical method was used

to assess the characteristics of the impact on Ukraine's foreign trade, forming the basis for analysing this information on past data, analysing it in retrospect. Abstraction was also used, which made it possible to ignore the impact of certain factors on a country's foreign trade if their real impact on it is too small. This helped to improve the accuracy of the models built during the study. The forecasting method was also used to assess the future development of Ukraine's international trade based on the information collected so far. Statistical analysis methods were used to analyse quantitative data, in particular, the volume of the country's foreign trade. All the calculations were made in Microsoft Excel.

▸ Results

To begin with, it is worth noting that international trade in general is always beneficial for the economic development of the countries between which such relations take place. The reason for this is that, in the case of trade between countries, each country focuses on producing goods whose relative production costs are minimal and buys those whose production costs are more expensive. However, despite this, various barriers that restrict or make trade between individual countries impossible are still widespread around the world. Moreover, this is still the case despite all the WTO's efforts to create freer trade relations between countries (Larch *et al.*, 2019). The organisation's overall function is to promote free trade (entering into trade agreements and treaties aimed at reducing tariffs and non-tariff barriers (Baier *et al.*, 2019). However, opinions on the real effectiveness of this organisation vary (Mahmudlu, 2021). While it cannot be denied that trade conditions between the countries have admittedly become freer in recent years, some differences still exist. WTO has also been criticised for being slow to resolve conflicts, as the mechanisms for doing so are too lengthy and complex.

The types of restrictions themselves can be varied. The most common tariffs are those levied on imported goods upon entry into the country. Tariffs can be specific (a fixed amount per unit of goods) or ad valorem (a percentage of the value of the goods), but in any case, they have the same goals: to provide the state budget with funds, to make it more difficult for other companies to enter the market, and to improve conditions on the domestic market for local producers (Ibragimova, 2020). International companies entering such a country will be forced to raise their prices compared to the world market. Another analogous instrument is a quota, which is a restriction on the amount of goods that can be imported into a country during a certain period. This can be a restriction on the quantity of goods, the amount of value, or any other indicators. In this case, the advantage is that the state itself understands exactly how much of a product will be sold on the market, which simplifies the activities of enterprises in the market. States also impose other types of restrictions, which may be related to, e.g., quality control of products imported into the domestic market or their compliance with environmental standards. Although formally related to health and environmental protection, such measures may also be imposed to reduce the impact of a particular company or companies on the domestic market.

Thus, the reasons for imposing restrictions on free trade by a country may vary. They may vary from case to case and may be either realistic or not optimal in a given situation (Furceri *et al.*, 2020). For instance, every country has strategically important industries that need to be developed within the country. These include agriculture, medicine, energy, etc. There is a reasonable need to introduce various restrictions for such areas of activity, as this will increase the country's resilience to various international crises (reducing dependence on prices for key products vital to the country). Such industries also include those that generate a relatively significant amount of added value in the manufacture of their products, such as machine building, aircraft construction, etc. Often, the reason for introducing such restrictions is considered as having social consequences, e.g., restrictions on foreign companies are imposed in industries that can create many jobs domestically. However, this reason is insufficient to support such an industry, as its development may prove to be completely inefficient for the country in the long run. This situation is similar to the failure of machines in agriculture to provide traditional tools to maintain the number of jobs in the country. Thus, the introduction of such restrictions can often be unjustified and caused either by a lack of awareness of the people who introduce them, or by populism, or any other analogous reasons.

In contrast to restrictions, there are trade agreements that, on the contrary, pursue to improve the level of trade between countries. They often reduce tariffs and duties, as well as any other restrictions related to the difficulty of entering the market. Most often, the formation of such agreements is related to economic expediency (under such agreements, countries reduce restrictions on certain groups of goods, joint trade in which is particularly important and profitable for them) or political expediency (the emergence of such agreements may be one of the steps to strengthen strategic alliances between countries). Although from an economic standpoint, such interaction should necessarily lead to improved economic development, this is not always the case. This is especially evident in the case of trade agreements between a large and a small country: in this case, the main beneficiary is often the large country, while for the small country, the fact of the alliance is more important than economic prosperity. The latter is the reason such agreements exist. The conclusion of such agreements should generally lead to an increase in trade between the countries, which may include a reduction in customs tariffs, legalisation of certain types of trade, and simplification of customs, and other administrative procedures. This expansion provides local producers with access to new markets, which expands their sales opportunities and increases their competitiveness in the international market. Furthermore, this may cause a decrease in the cost of such goods for consumers in both countries. All these components form the main reason why international trade liberalisation, and thus the conclusion of trade agreements that facilitate it, most often lead to net gains for society. It is also worth considering how trade agreements affect trade by analysing statistical data. Figure 1 shows Ukraine's foreign trade performance in 1989-2022:

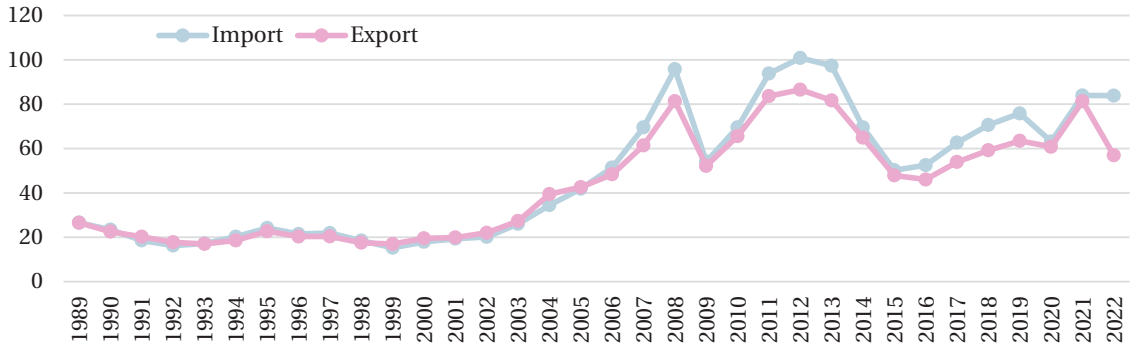

Figure 1. Data broken down by Ukraine's trade volumes in 1989-2022, USD billion
Source: compiled by the authors of this study based on Exports of goods and services (current US$) – Ukraine (n.d.); Imports of goods and services (current US$) – Ukraine (n.d.)

As Figure 1 suggests, Ukraine's foreign trade is quite volatile and heterogeneous; the graph shows various trends in its development (both upward and downward), which were determined by both the current global situation and the situation related to Ukraine (specifically, the trends in trade to gross domestic product (GDP) after the outbreak of the war with Russia in 2014 changed significantly), and is therefore also part of certain international trade agreements. To analyse the impact of trade agreements on Ukraine's international trade, it was decided to evaluate the data on the number of regional trade agreements (RTAs) and inflation-adjusted international trade volumes. Generally, the country is a relatively active participant in international trade (as evidenced by the ratio values). The number of transactions is presented in Figure 2 below:

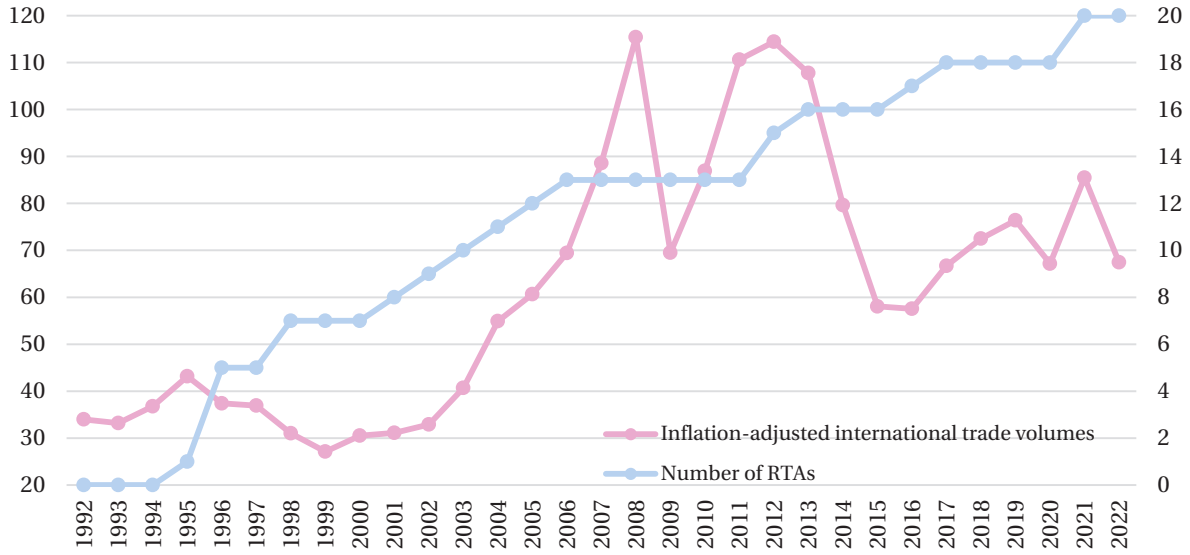

Figure 2. International trade volumes adjusted for inflation (USD billion) and the number of RTAs in Ukraine from 1992 to 2022
Source: compiled by the authors of this study based on Exports of goods and services (current US$) – Ukraine (n.d.); Imports of goods and services (current US$) – Ukraine. (n.d.); RTAs currently in force (by year of entry into force), 1948-2023 (2023); Inflation calculator with U.S. CPI data (n.d.)

As Figure 2 suggests, inflation-adjusted international trade and the number of regional trade agreements are both on an upward trend. Often, the growth of international trade in Ukraine was caused by the conclusion of new agreements, while the unchanged number of agreements led to stagnation or no growth in the number of RTAs. This is also confirmed by statistical indicators: specifically, the correlation level between the indicators is 0.66, which is quite high. Therewith, if one builds a linear regression equation in terms of the interaction between the indicators, it will be statistically significant (the p-value for both values is below the threshold of 0.05). The equation constructed in this way, with trade volumes as the dependent variable and the number of RTAs as the independent variable, is as follows:

$$y = 28.414 + 2.964x, \quad (1)$$

where y is the volume of international trade of Ukraine; x is the number of RTAs.

Thus, trade agreements have a significant impact on Ukraine's foreign trade, and thus on the entire country's economy. The agricultural sector plays a special role in Ukraine's foreign trade, particularly in ensuring its stability. Ukraine has significant potential for growing a variety of crops and producing food, including grains, oilseeds, sugar beet, meat, and milk. Exports of agricultural products help attract foreign currency and increase the country's solvency. It is also an essential component of food security, as it reduces dependence on food imports, allowing the country to ensure food security and control food prices. It also allows for the development of rural areas, creates jobs, and influences other industries, e.g., allowing for the development of biofuel production. Thus, Ukrainian agriculture is a key component of economic development and foreign trade in general. The trade in these products has its own specific features. Thus, crop and livestock production is highly dependent on natural conditions such as climate, soil, topography, and water availability, making some countries highly dependent on agricultural products (if they are located in areas that are difficult to grow) (Jakob, 2021). Furthermore, many agricultural products are grown and harvested during specific periods of the year, leading to seasonal changes in agricultural trade, which requires efficient storage and transportation to extend the shelf life. In addition, some years may be poorly harvested due to changes in weather conditions, which affects the price and volume of products on the international market. Thus, all these factors should be considered when building more complex models related to the analysis of agricultural trade. Figure 3 presents the volume of foreign trade in this component of Ukraine:

Figure 3. Volumes of exports, imports, and foreign trade in Ukraine in 2003-2022, billion USD
Source: compiled by the authors of this study based on data from Trade Map (n.d.)

Figure 3 shows the gradual growth of Ukraine's imports, exports, and foreign trade in agricultural products over time in US dollar terms. It somewhat resembles the configuration presented above in Figure 2. Figure 4 presents inflation-adjusted foreign trade volumes and the number of RTAs:

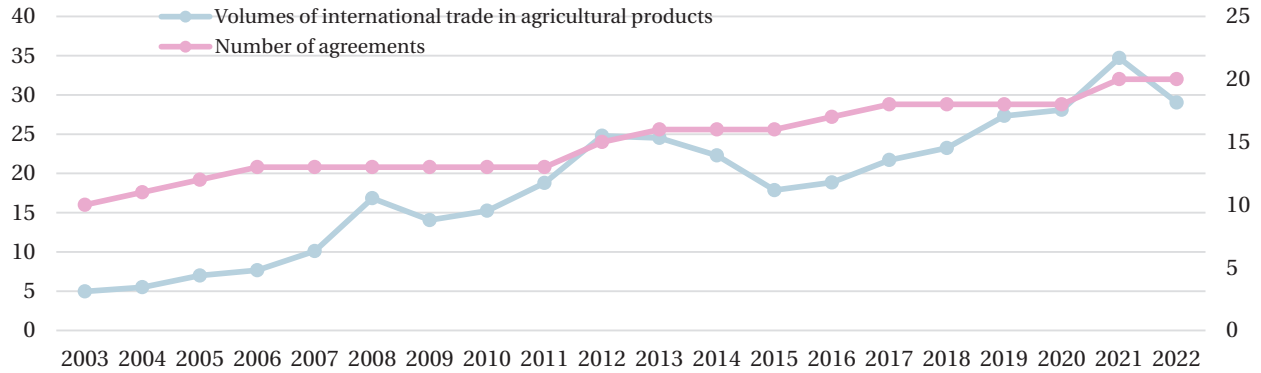

Figure 4. Volumes of foreign trade in agricultural products adjusted for inflation (USD billion) and number of RTAs
Source: compiled by the authors of this study based on Trade Map (n.d.); Inflation calculator with U.S. CPI data (n.d.)

As Figure 4 suggests, the volume of foreign trade in agricultural products in Ukraine is also strongly correlated with the number of international agreements concluded. However, more detailed information on their interaction can be obtained by estimating the regression equation presented in Formula 2:

$$y = 9.2688 + 0.3157x, \quad (2)$$

where y is the volume of Ukraine's international trade in agriculture; x is the number of RTAs.

Other characteristics of the model are as follows: R^2 (Adjusted) – 0.81; Significance F and p-value – close to 0. In other words, according to this model, the number of RTAs explains 81% of the changes over time in the indicator of international trade in agricultural products. At the same time, all variables are significant, and the model is

adequate. All this suggests a very significant interaction between the number of agreements concluded between countries and the volume of international trade in agricultural products. However, these conclusions are based on information from only 20 observations, as more information on foreign trade in agricultural products is not currently available. Therefore, it is worth conducting additional research in the future on this issue to draw final conclusions.

▸ Discussion

T.P. Cuong & N.H. Tien (2022) investigated the role of international trade in international business in their research. The scholars emphasised the importance of implementing the right and relevant trade policy to exploit comparative advantages in international trade and expand regional and global markets, as well as the need to focus on selecting the most profitable products and markets for international trade development. Furthermore, they noted the importance of developing a comprehensive legal framework for commercial activities both domestically and internationally, as well as simplifying the conditions for international trade (reducing or eliminating various conditions, restrictions, etc.). Notably, such recommendations would be useful for Ukraine, but not in a time of war. In this case, trade policy should be special: the reason for this is that the state as such is in dire need of increased budget revenues to finance all the costs associated with the war. Furthermore, the security of citizens is reaching a new level, and various dangerous items can be brought into the country along with goods obtained through international trade. Thus, trade policy in this case should be stricter, and special (even greater) attention should be paid to customs issues and how they make decisions on whether to allow goods into the country. S.L. Baier & J.H. Bergstrand (2007) investigated the impact of free trade agreements on international trade flows. The researchers showed that such agreements generally had a significant and positive impact on international trade flows. Specifically, on average, they have doubled bilateral trade between two member states every 10 years, which is an impressive rate. Thus, their use can be considered effective and qualitative for the countries.

P. Barlow *et al.* (2021) studied the impact of the COVID-19 crisis on global trade. They noted that the global pandemic has caused considerable damage to world trade but has allowed governments to reassess globalisation and develop trade policies. Scientists believe that trade policy in the future should also contribute to a more sustainable development of people, enabling them to be healthier than before. They write that the link between trade and health exists because of the spread of disease during the pandemic through trade routes; therefore, policy makers should consider the broader links between trade, trade policy, and the determinants of health. In general, this approach makes it even more difficult to form interactions between countries in terms of trade agreements. A. Berger *et al.* (2020) conducted studies on how environmental regulations affect international trade. The researchers concluded that environmental provisions in preferential trade agreements do not constitute significant restrictions on the exports of developing countries. Thus, environmental provisions in these agreements can help reduce dirty exports and promote green exports from developing countries, creating win-win scenarios for economic and environmental benefits. They can be effective policy tools to counteract the potential effects of pollution. In other words, the researchers believe that the introduction of such restrictions may ultimately prove beneficial for both countries, as it will reduce trade, but not significantly, and therefore will have an overall positive impact on the countries.

W. Saraithong (2018) substantiated the existing trade restrictions for food safety implementation. Generally, as described above, such restrictions related to ensuring the development of certain strategically important industries can be considered almost the only ones that are rational on the part of the country. However, the scientist noted that the state's actions related to the establishment of such restrictions may in fact be caused by different reasons. This can be done both to protect and increase budget revenues and to improve the social health of citizens. The study highlights the importance of understanding both domestic factors and changing global contexts in the application of food safety standards. This emphasises the need for stakeholders to closely monitor multilateral and bilateral trade negotiations, as they may have a substantial impact on the implementation of such restrictions.

C. Tortajada & F. González-Gómez (2022) investigated the impact of international trade in food and agricultural products in the context of groundwater depletion. Scientists have described that since 1995, trade in food and agricultural products has doubled in real terms, specifically due to the development of developing countries. In this regard, food production was also increased successfully. However, all this has had a negative impact on environmental development opportunities, namely through the exploitation of groundwater. Considering this, scientists are calling for more attention to be paid to this component, especially to the development of relevant environmental policies. Scientists also suggested that regions and countries consider growing less water-intensive crops and convert irrigated agriculture to rainfed agriculture to adapt to climate change. However, all such changes must be driven by the influence and support of government agencies. Generally, in the current context, ensuring agricultural sustainability is admittedly an essential component of development for Ukraine, but due to Russia's full-scale invasion, these issues have been put on the back burner. Nevertheless, after the end of the war, government officials should pay much more attention to environmental issues in the agricultural sector.

R. Barichello (2020) described the impact of the COVID-19 pandemic and predicted its impact on Canadian agricultural trade. The scientist noted the general adverse impact of this crisis on the economy of developing countries, and on international trade specifically. However, it had a lesser impact on agriculture due to the lower elasticity of income to demand. In terms of the prospects for the growth of agricultural trade in Canada, the scientist notes that it exists, but on a different scale in different categories. Thus, cereals are expected to perform relatively better, while legumes are expected to drop. A slightly different situation in terms of trade in agricultural products was observed in the study above. In Ukraine, the volume of trade in these products has only increased,

driven by the country's focus on grain exports and rising prices. Thus, the pandemic, as well as crises, can have a different impact on sales of agricultural products, which should be considered when formulating policy in this area.

Thus, restrictions and trade agreements do have a significant impact on international trade, and on trade in agricultural products specifically. However, other factors should also be considered when shaping international policy. Therefore, in Ukraine's current circumstances, to increase international trade, it is vital not only to pay attention to trade agreements and interaction between countries, but also to the situation within the country, to support internal producers affected by the war, etc. Only then will it be possible to achieve success in ensuring the development of foreign trade.

Conclusions

Thus, international trade plays a key role in the economic development of countries around the world, including Ukraine. It also contributes to global economic growth by attracting foreign investment, which has a lasting positive impact on economic development. Despite the many benefits of international trade, barriers and restrictions continue to be imposed by countries. Unlike trade restrictions, trade agreements are aimed at expanding trade between countries. In most cases, they lead to improved economic development of countries through various effects: increased market access for local producers, foreign investment, and lower costs for consumers. The same result was achieved when assessing the statistical data characterising Ukraine's foreign trade. It was proved that the number of valid trade agreements affects the volume of trade and leads to an increase in its volume.

The same assessment was made in terms of agricultural exports. It was shown that this sector plays a significant role in foreign trade and in overall food security. Analysing the relationship between the number of RTAs and the volume of international agricultural trade in Ukraine, a significant correlation was found: it was shown that they account for 81% of all changes in the volume of agricultural trade. This highlights the significant impact of trade agreements on agricultural trade and, as a result, on the country's economic development. All this suggests the importance of strengthening future cooperation between Ukraine and other countries in the context of international trade in the future.

It is relevant for future research to create a strategy for the development of Ukraine's international trade, with a focus on the existing problems associated with Russia's full-scale invasion. Furthermore, it is vital to analyse international practices in this area to find methods that can be used in local realities.

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None.

Conflict of Interest

The authors of this study declare no conflict of interest.

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Вплив торговельної політики та угод на розвиток міжнародної торгівлі в аграрному секторі України

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► **Анотація.** Міжнародна торгівля нині є одним із основних видів міжнародних відносин, без існування яких неможливо уявити сучасне функціонування будь-якої економіки. Таким чином, актуальним залишається проведення досліджень впливу різних видів державної політики та окремих угод на даний вид відносин та власне розвиток країн. Ціллю даного дослідження було показати, яка існує взаємодія між зовнішньої діяльністю та обсягами її торгівлі в сфері сільського господарства на прикладі України. Основними методами дослідження, що були використані під час написання, стали аналіз, прогнозування та абстрагування. В рамках роботи було описано роль міжнародної торгівлі, зокрема в аграрному секторі зважаючи на його роль для економічного розвитку країни. Було коротко описано роль міжнародної торгівлі з теоретичної точки зору. В рамках дослідження, на основі аналізу статистичних даних, було також показано який вплив чинить вкладення торговельних договорів на розвиток зовнішньої торгівлі. У розрізі дослідження аграрної економіки було показано, що поступове зростання обсягів українського аграрного експорту, імпорту та зовнішньої торгівлі сильно пов'язані із кількістю укладених торговельних угод. Було побудоване відповідне рівняння залежності величин, а також пояснено його економічний сенс. Також описувалася роль сектору в цілому, а зокрема в сучасний умовах військового стану. Особливу увагу було приділено аграрному сектору України, який відіграє вирішальну роль в економічному розвиткові. Було обґрунтовано роль даного сектору та унікальні характеристики галузі. Відмічався сильний взаємозв'язок між кількістю торгових угод та обсягом міжнародної торгівлі в аграрному секторі України за допомогою проведеного регресивного аналізу, на основі чого формувалися висновки з приводу ролі торговельних угод для розвитку міжнародної торгівлі продукцією аграрного сектору. Дане дослідження приносить нові знання у розрізі оцінки ролі міжнародної торгівлі для розвитку країни, а також аналізу сучасного стану економіки України в цілому

► **Ключові слова:** макроекономіка; державна політика; управління; міжнародні відносини; розвиток

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Priority areas for the development of field fodder production in view of the climate crisis

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► **Abstract.** This article covers the topical issue of the general impact of climate change on Ukrainian agriculture and on the field fodder production industry specifically, as well as the problems of adapting agriculture to modern environmental conditions. The authors set out to substantiate promising ways of developing modern field fodder production considering climate change. For this, the study employed the abstract-logical method, system analysis, methods of systematisation and classification, and a range of economic and statistical research methods (comparison, series of dynamics, method of structural groupings). Both negative and positive manifestations of the climate crisis in crop production were highlighted, and possible measures to counteract risks and ways to use potential opportunities to develop field fodder production given the impact of climate change were systematised. Particular attention was paid to the global practices of agriculture in the face of climate change, namely, the components of a climate-smart crop production system. The study also described the main promising measures of adaptation of field fodder production to climate change: irrigation of agricultural land, arrangement of snow retention systems in the fields, rainwater harvesting, selection and introduction of new varieties of fodder crops, effective crop rotation, increase in sowing of drought-resistant

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fodder crops, optimisation of agricultural technologies to reduce losses of fodder crops at the stages of harvesting and storage, application of organic farming, the latest soil fertilisation technologies and the use of nanotechnology in soil cultivation. The findings of this study can be used by managers of specific agricultural enterprises, as well as by advisory services and government agencies in the field of agricultural policy implementation

▸ **Keywords:** fodder crops; climate change; irrigation; organic farming; sorghum

▸ Introduction

Many scientific studies have been conducted to investigate the state of the livestock and crop production sectors in various economic entities and to substantiate possible prospects for their development in the context of climate change. Ukrainian scientists are studying the impact of climate change on agriculture and proposing adaptive agricultural measures. S.P. Ivanyuta *et al.* (2020) consider the main manifestations of the impact of climate change on various sectors of the national economy and factors of fodder production: land and water resources, energy efficiency of agriculture. L. Melnichenko & A. Bondarenko (2021) focus on various adaptive mechanisms of agrocenoses to modern climatic conditions. V.M. Pysarenko *et al.* (2020) describe the best agricultural technologies that can be applied in conditions of moisture deficit. Y. Yarochenko (2022) describes promising areas of energy-saving agricultural production. However, these and other studies reflect the specific features of adaptive farming in the field of crop or livestock production, while the issues of field fodder production and priority areas of development of this industry considering the climate crisis are understudied. V.F. Petrychenko *et al.* (2018), considering promising avenues of developing fodder production, focus on adaptive technologies for growing fodder crops and breeding new varieties, but they lack the consideration of the modern climatic reality.

Foreign scientists are also researching climate change adaptation at the level of agriculture in general, not in the field of fodder production. N.P. Simpson *et al.* (2023) offer detailed research on the risks associated with climate change. Specifically, these are the risks of lower crop yields, complete loss of crops, and higher production costs in the agricultural sector. W. Elnashar & A. Elyamany (2023) focus on the problems of water scarcity and the need for irrigation on agricultural land in the new climate conditions. The current trends in temperature and water supply, and the frequency of abnormal weather conditions that can affect agriculture were also described (IPCC, 2022).

Since the 2000s, significant environmental and climatic changes have been observed around the world, affecting not only the well-being of the population, but also changes in animal behaviour and territorial boundaries, and disruption of plant habitats. Climate change is also having a considerable impact on human economic activity. The effects of this impact are particularly pronounced in crop production and field fodder production, as crops are sensitive to natural and climatic factors.

Ukraine is facing the challenge of optimising its fodder production model and finding effective solutions to counteract the adverse impact of natural and climatic factors. This requires, on the one hand, the adoption of measures to achieve the goals of adaptation to climate change, and, on the other hand, the implementation of measures aimed at reducing the adverse impact of field fodder production on the natural and climatic state of the environment. The purpose of this study was to identify promising ways to develop field fodder production in the context of climate change. This purpose requires completing a range of research objectives: to identify the positive and negative effects of climate change in field fodder production; to investigate the mechanisms of climate change impact on the industry; to propose measures to counteract the adverse impact of climate change in the field of fodder production and areas for the effective use of the positive impact of climate change.

▸ Materials and Methods

Proceeding from the purpose of this study and its objectives, the appropriate materials and the best research methods were employed. The research materials can be systematised into several main groups: regulatory sources, specifically, the Law of Ukraine "On Land Lease" (Law of Ukraine No. 161-XIV..., 1998), the Strategy for the Restoration and Development of Irrigation and Drainage Systems in Ukraine until 2030 (Decree No. 688-p..., 2019), etc., data from theoretical and practical scientific research (monographs, publications in specialised literature, Internet publications), statistics on climate change, trends in the decline in fodder crop yields (Agriculture, forestry and fisheries, n.d.), forecast data provided by experts from specialised organisations (Ivanyuta *et al.*, 2020). Essential research materials included statistical data on the share of irrigated land in Ukraine and in some countries of the world (both Asian and European), on the area of sorghum crops in Europe and in Ukraine (Agriculture, forestry and fisheries, n.d.). An equally essential group of materials included the findings of scientific experimental studies and practical observations that allow comparing the yield of individual fodder crops with each other when grown under the same weather and climate conditions, the yield of the same crop when grown at different temperatures and water availability, etc.

In preparing this study, the method of analysis was primarily used, which elaborates on theoretical provisions on climate change and its impact on various spheres of society, specifically, on the agricultural sector, and examines possible areas of investment. Using the synthesis method, the areas of further development strategy of field fodder production were formed and the main ideas and vectors of development of scientific thought on the impact of climate change on agriculture and vice versa were formulated. The theoretical and methodological provisions of the subject under study were summarised using a systematic analysis. Agro-climatic processes are considered as a single interdependent system of elements: on the one hand, the cultivation of fodder crops and their yields are

closely dependent on weather and climate conditions; on the other hand, field fodder production affects the climate. The mechanisms of climate change impact on field fodder production were studied using the methods of systematisation and classification, which allowed identifying direct and indirect, as well as positive and negative impacts. Similarly, the areas of meeting the growing demand for fodder were systematised, with extensive and intensive ways of doing so identified. Statistical data were processed and analysed using economic and statistical research methods (comparison, time series, method of structural groupings). Thus, the comparison method made it possible to identify the most productive fodder crops when grown under dry conditions. The comparison also helped to assess the fodder value of certain crops, such as maize and sorghum. The time series method helped to track changes in statistical data over the relevant period of time. The method of structural groupings made it possible to characterise the share of certain aggregates (e.g., the share of irrigated land among all agricultural land in Ukraine and the world). For effective perception of statistical data and research results, tabular and graphical methods of visualisation of materials were used. The abstract and logical method was used to interpret the data in the statistical tables.

▸ Results and Discussion

The impact of climate change on field fodder production is quite complex and multidirectional, and it is possible to form positive and negative aspects of such an impact. Depending on the concrete situation, either the negative or the positive impact of climate change may prevail. However, scientists have already proven that the negative effects of climate change are more pronounced (Table 1).

Table 1 shows the direct effects of climate change on the field fodder industry. However, there is also an indirect impact that takes place through other sectors of agriculture. The primary mechanisms of such influences are summarised in Figure 1.

Table 1. Positive and negative effects of climate change in field fodder production

Negative manifestations	Positive manifestations
Decreased fertility and deterioration of soil conditions	longer growing season for growing fodder crops
Reduced yields of fodder crops	shifting the growing areas of heat-loving fodder crops to the north
increased activity of agricultural pests, increased frequency of fodder crop diseases	better conditions for wintering biennial and perennial fodder crops
frequent droughts and floods	increase in the yield of cereal fodder crops under the influence of an increase in the concentration of carbon dioxide in the atmosphere

Source: compiled by the authors of this study using data from L. Melnichenko & A. Bondarenko (2021)

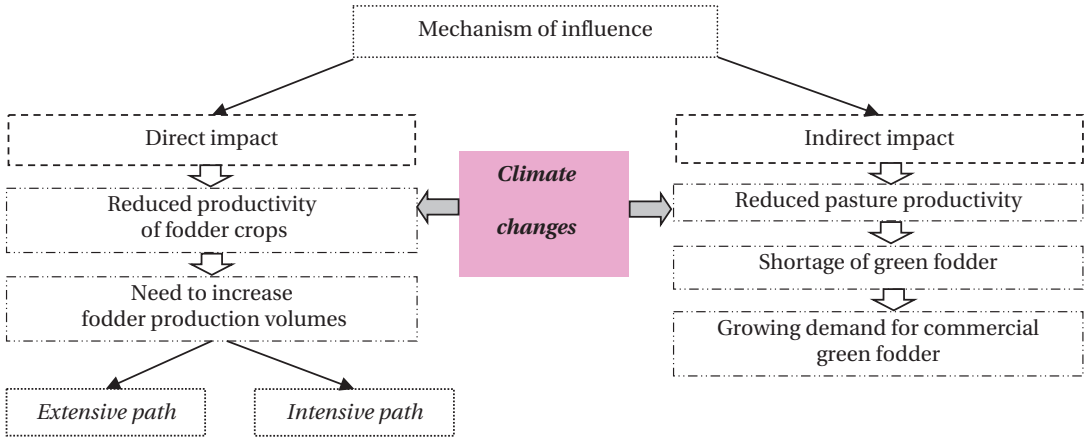

Figure 1. Mechanisms of climate change impact on the field fodder industry
Source: compiled by the authors of this study based on research by L. Melnichenko & A. Bondarenko (2021); Y. Yarochenko (2022)

As presented in Figure 1, from an economic perspective, the impact of climate change on commercial field forage production is positive, as it creates additional demand for fodder. This is due to a possible shortage of green fodder in livestock production. According to research by Y. Yarochenko (2022), small agricultural enterprises use more than 30% of green fodder in the overall feeding structure, while large agricultural enterprises use about 15%. Based on these data, it can be concluded that the emergence of a shortage of this fodder component will increase the demand for commercial fodder and stimulate commercial field fodder production.

In such circumstances, agricultural enterprises are faced with the task of choosing a path for further development:

1) The extensive path requires an increase in the area under fodder crops;

2) The intensive path involves achieving the goals of increasing the yield of fodder crops (using new varieties,

new crops, optimisation of nutrition and moisture for fodder crops, etc.)

The extensive way of further development of fodder production has its obstacles at various levels of management: at the level of an individual enterprise, region or state, an increase in the area of farmland under fodder crops will lead to a loss of sown area for grain crops, which are traditionally the most profitable, in high demand, and exported outside Ukraine, forming its solvency. That is why the extensive development of fodder production is not promising at present. Accordingly, measures to intensify field fodder production are needed. They can be aimed at reducing the negative impact of climate change or at more efficiently harnessing its positive effects on the industry under study. The most popular and effective ways to reduce the adverse impact are summarised in Table 2.

Table 2. Ways to counteract the adverse impact of climate change in the fodder industry

Adverse impact	Countermeasures
1	2
Decrease in soil fertility	1) measures to improve soil fertility: - application of the latest soil fertilisation technologies; - use of nanotechnologies for soil cultivation; - state control of soil quality. 2) growing fodder crops that are less demanding on soil fertility
Reduction in overall crop productivity	1) optimisation of breeding work: - breeding fodder crops with high productivity and adapted to modern climatic conditions; - use of varieties previously grown in more arid regions; 2) growing new fodder crops; 3) reduction of losses of fodder crops during harvesting and storage
Increased spread of crop pests and diseases	1) growing crops and varieties resistant to pests and diseases; 2) application of pest and disease control measures
Increased frequency of extreme events related to water resources	1) growing drought-resistant crops and varieties; 2) installation of irrigation systems; 3) arranging snow retention systems on the fields and rainwater collection

Source: developed by the authors of this study based on research by S. Baliuk *et al.* (2017); Y. Yarochenko (2022)

As for the issue of soil fertilisation, there are two opinions in scientific sources on the feasibility of applying different soil fertilisation schemes in the context of climate change:

1. *The first opinion is to optimise the application of mineral fertilisers.* For instance, this idea is supported by S. Baliuk *et al.* (2017). Scientists note that in the context of climate change, it is necessary to increase the volume of phosphorus and potash fertilisers rather than nitrogen fertilisers. Rising temperatures and decreasing humidity, which currently accompany climate change, limit the rate of nutrient movement in fodder crops, while slowing the growth of their root system. And in conditions of water shortage, it is the branched root system that contributes to the normal development of plants. For its formation, the presence of mobile forms of phosphorus in the soil is important. Therefore, the application of phosphate fertilisers helps to optimise the root nutrition of fodder crops, which considerably increases their access to soil moisture and improves water consumption of crops even under conditions of unstable moisture. As a result, the adverse impact of climate change is reduced, and the productivity of fodder crops stays high. These effects of phosphate and potash fertilisers were proven experimentally. Practical experiments have shown that the amount of bound water, which determines the resistance of crops to high temperatures and drought, increases by 12-50% when phosphate-potassium fertilisers are applied to the soil. Scientific research suggests that phosphorus fertilisers contribute to better root development, while potassium fertilisers improve moisture use in conditions of moisture deficit through more intensive development of both leaves and roots of forage crops (Baliuk *et al.*, 2017).

2. *The second opinion is that in the context of climate change, it is necessary to minimise mineral fertilisers and replace them with organic ones.* For instance, many countries, especially Germany, France, the Netherlands, Poland, etc., are already actively practising a system of agriculture called CSA (Climate Smart Agriculture) (Ivanyuta *et al.*, 2020). This system is aimed not only at adapting agribusiness to the new conditions associated with climate change, but also at minimising the adverse impact of agriculture on the environment. Achieving these goals involves a system of measures, including special methods of mechanical soil cultivation, optimisation of waste management, revegetation, soil reclamation on pastures, optimisation of manure storage and use, energy saving measures, decarbonisation, transition to growing more drought-resistant and high-yielding crop varieties, silvicultural reclamation, etc. The most common use of CSAs is in organic production (Ivanyuta *et al.*, 2020). V. Radulescu *et al.* (2021) also discuss the prospects for the development of this agricultural technology. Scientists note the growing demand for organic agricultural products and, at the same time, the positive impact of organic farming on the climate. Specifically, this technology involves the use of organic fertilisers. The main mechanism of this farming system's impact on the general adaptation to climate change in agriculture, and fodder production specifically, is associated with an increase in the water resistance coefficient of structural units. According to V.M. Pysarenko *et al.* (2020), in the case of an

organic farming system, it reaches 10%, while in an intensive farming system it is only 5.2%. The main effects of organic farming in field fodder production are determined by the effects described in the study by L. Datsko (2018): an increase in humus content; improvement of soil structure and reduction of soil acidity; saturation of soils with macro- and microelements, phytohormones, enzymes, and amino acids; and improvement of plant access to carbon dioxide. Apart from changing approaches to fertilisation to counteract the negative impact of climate change, it is important to use efficient crop rotations with fodder crops in them, as most of them can restore soil fertility by increasing humus content, improve soil nutrient and moisture supply, and improve physical properties and soil structure. Grow How company experts note that green manure is the most effective in this aspect, as it provides increased biological activity, loosening of the topsoil, reducing its acidity, increasing sunlight reflection and, accordingly, preventing overheating of the earth (Soil moisture: How to measure and preserve, 2021).

A considerable part of agricultural land in Ukraine is currently leased under the Law of Ukraine "On Land Lease" (Law of Ukraine No 161-XIV..., 1998). Lessees are not interested in investing in measures to restore and maintain land fertility. In most cases, the indicators of soil fertility changes during the term of the lease are not monitored. Therefore, the factual user of the leased land plot (the lessee) is not motivated to improve soil fertility, especially if they plan to lease and use the land for a short time (several years). As a result, after the lease expires, the lessor (most often a citizen, land plot or share owner) receives extremely depleted land with extremely low soil fertility. Sustainable agricultural land use requires information on the quality of agricultural land and soil fertility. For instance, currently in Ukraine, land leases are carried out without the obligatory accompaniment of an agrochemical passport for a land plot. The absence of a passport for an agricultural land plot has a negative impact on the efficiency of land use. The depletion of land should be punishable by fines, and the improvement of its condition should be stimulated by benefits, etc. That is why N.A. Sprynchuk (2011) emphasises the need for mandatory control over land quality by the state, as this will have a generally positive impact on the condition of soils. Combining information about soil conditions and field forage production is possible using intelligent digital technologies that surpass human capabilities. As noted by N.P. Simpson *et al.* (2023), risk and uncertainty are increasing, and climate change, limited availability and cost of resources, and market volatility are constraining decision-making by both policy makers and farmers. These trends are leading to a new era in which digital technologies make it possible to control both the condition of the soil and the condition of agricultural plants, and their combination creates the possibility of obtaining stable yields.

The prospects for counteracting the negative impacts of climate change in field fodder production are also significant in the field of breeding. It is relevant to develop new varieties and hybrids of fodder crops that are highly resistant to temperature fluctuations and moisture deficit. The authors of this study agree with S. Baliuk *et al.* (2017) that for early crops, the rapid growth of the root system and aboveground biomass becomes a particularly vital feature, which creates opportunities for the rapid development of fodder crops during the period when the soil still has sufficient moisture content. According to M. Aksaniuk (2021), the specialists of the Institute of Plant Breeding and Genetics have been conducting adaptive crop breeding for a long time. Over the past 15 years, they have developed and entered 183 varieties and hybrids of winter wheat, winter and spring barley, sunflower and maize, peas and soybeans, chickpeas and sorghum, alfalfa and sainfoin into the state register. These data indicate that breeding is quite active not only for grain crops, but also in fodder production. Many of the new varieties are not only characterised by high yields and short ripening periods but are also drought and frost resistant. They are being successfully tested in Ukraine and in other countries (Spain, Romania, France, Turkey, Georgia).

Using the results of breeding work to develop early-ripening varieties that are highly resistant to sudden changes in temperature, moisture deficit or excess, one can harvest twice a year. Thus, after harvesting winter barley or wheat in July, it is recommended to sow early maturing hybrids of soybeans, sunflower, millet, and fodder crops. This practice has long been used by agribusinesses in Israel, Turkey, and other countries with challenging climatic conditions. In these countries, agriculture requires irrigation, and it is the harvesting of crops twice a year that makes it profitable (Aksaniuk, 2021).

Agrotechnical measures should also be an essential part of counteracting the negative impact of climate change in field fodder production. To adapt to climate change, agricultural enterprises must introduce modern technologies and methods of growing fodder crops. First of all, this concerns measures to accumulate and save water from precipitation and soil moisture, as water regime is a major factor of fertility, which is primarily affected by climate change. At the same time, as noted by S. Baliuk *et al.* (2017), it is considered a difficult to control factor, as it depends on natural features: the amount of precipitation (which can be considerably reduced in the context of climate change), soil properties in terms of moisture retention (deteriorates with a decrease in humus, disruption of soil structure), unproductive water losses through evaporation, and increased surface or infiltration runoff.

The main measure to counteract droughts and other extreme effects of climate change related to water resources is the development of irrigation systems. This is an agricultural technology that has a direct impact on the negative environmental factor in the context of climate change, compensating for the shortage of natural moisture, ensuring sufficient water supply by redistributing water from places of its availability to agricultural land. Therewith, irrigation becomes effective only in combination with other agrotechnical measures: the use of appropriate tillage systems, adherence to best fertilisation schemes, chemical reclamation, weed and pest control, etc. S.P. Ivanyuta *et al.* (2020) acknowledge that in the context of climate change, an increase in the area of irrigated land is necessary for climate-optimised agriculture. Such recommendations are relevant for temperate countries, including Ukraine, which may face water shortages as a result of climate change. Therefore, with the support of the World Bank

and the Food and Agriculture Organisation of the United Nations (FAO), the Strategy for the Restoration and Development of Irrigation and Drainage Systems in Ukraine until 2030 was developed for Ukraine (Decree No. 688-p..., 2019). It is intended to create an effective mechanism for the provision of irrigation and drainage services to ensure efficient agriculture in the country (Baliuk *et al.*, 2017).

T. Zinchuk *et al.* (2021) emphasises the multidirectional trends of land reclamation processes in Ukraine and in the world. Thus, considering the climate change, the area of irrigated land on a global scale is growing by 1% annually, while in Ukraine this figure has decreased by 70% over the past 20 years. And this is despite the fact that irrigation is one of the primary factors that reduces the dependence of agribusiness on natural moisture supply and creates conditions for increasing crop yields. According to the scientist, the efficiency of the yield increase from growing oilseeds under irrigation compared to the average is 6.9 c/ha. In the case of soybean cultivation under irrigation, the yield increase is the highest – 9.4 c/ha, while sunflower is 4.9 c/ha. As of 2022, the area of irrigated land in the world is about 300 million ha. The share of irrigated land in some Asian countries exceeds 40%, while in Ukraine this figure reaches only 1.1% (Fig. 2).

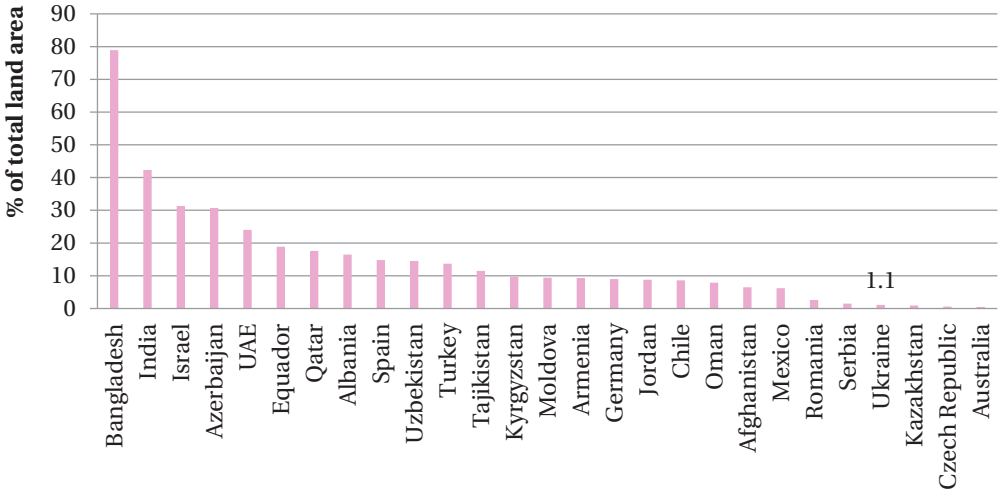

Figure 2. Share of irrigated land in selected countries in 2022
Source: compiled by the authors of this study based on data Agricultural irrigated land (% of total agricultural land) (n.d.)

In Ukraine, the area of available irrigated land, according to the State Agency of Water Resources, is about 2.17 million ha, of which only a quarter – 505 thousand ha – is actually irrigated (State water cadastre..., n.d.). In 2020-2022, irrigation volumes decreased significantly: while in 2020, 1,452 million m³ of water was used for these purposes, in 2022, only 143 million m³ was used (Fig. 3).

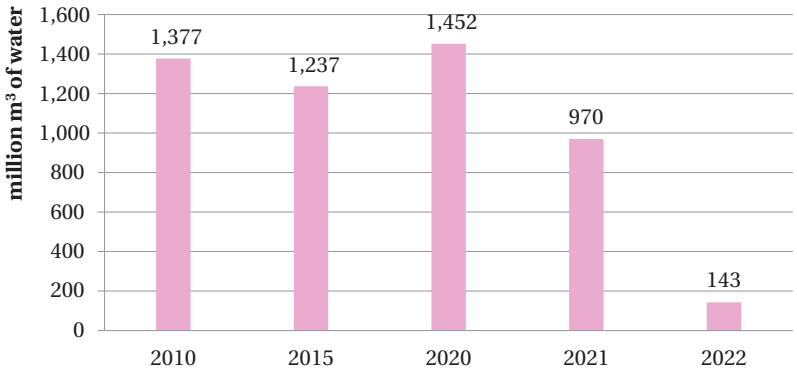

Figure 3. Water consumption for irrigation in Ukraine in 2010-2022
Source: compiled by the authors of this study based on Environment (n.d.)

Therefore, irrigation of land is quite relevant for Ukrainian farmers. But this requires considerable investment. The expansion of irrigated areas will cost the farmer about USD 2.6 thousand per hectare. Even with the losses farmers face as a result of droughts, they are not ready to invest in irrigation facilities, as about 90% of farmers grow crops on leased land while the moratorium on land sales continues. Without confidence in the possibility of extending leases or purchasing land in the strategic period, agribusinesses are not ready to invest in long-term irrigation projects (Zinchuk *et al.*, 2021). Accordingly, it is more promising for lessees and most landowners in Ukraine to use the positive impact of climate change on the develop-ment of field fodder production (Table 3).

Table 3. Ways to utilise the positive impact of climate change in the fodder industry

Positive impact	Effective use of the factor
increase in the length of the growing season	1) growing two harvests of agricultural crops; 2) shifting the timing of agrotechnical measures; 3) growing new fodder crops
Extension of the zone for growing heat-loving crops to the north	Growing varieties of fodder crops previously used in the southern territories
Optimisation of the physiological state of field crops in winter	Optimisation of crop care in winter

Source: compiled by the authors of this study based on research by L. Melnichenko & A. Bondarenko (2021); Y. Yarochenko (2022)

As Table 3 suggests, one of the most positive impacts of climate change on field fodder production is the increase in the length of the growing season. As noted by N. Honcharova & H. Meluta (2022), in Ukraine in 2022, compared to the 2000s, the duration of the active growing season has already increased by an average of 10 days. The forecasts until 2030 suggest that the period of growth and development of heat-loving crops will be extended by another 10 days. The Polissya and Forest-Steppe regions are warming faster than the steppe regions. Winter temperatures increased by 1.5-2°C, and the depth of soil freezing decreased to 20-70 cm, which is a favourable factor for the absorption of winter precipitation and the formation of sufficient soil moisture in spring. To make more efficient use of the growing season length factor, it is possible to, firstly, expand sown areas for species and varieties of fodder crops with a short growing season, which will allow for two to three harvests of individual crops; secondly, shift the sowing dates of spring crops to earlier and winter crops to later dates, which will ensure efficient use of soil moisture reserves by crops and create prospects for soil optimisation between spring and winter crops; thirdly, grow new fodder crops with a long growing season.

As noted by L. Hrustek (2020), agriculture, including field forage production, is faced with the challenge of growing more, polluting less, and distributing better (supply chain optimisation). Given the climate crisis, special attention should be paid to finding new fodder crops that can be grown in new climatic conditions. According to forecasts, climate change in the coming years will be manifested by a decrease in air temperature in the cold season and an increase in the warm season. Therewith, the amount of precipitation will decrease. It is expected that over the next 40-50 years, the climate in southeastern Ukraine will become more continental, which will be manifested by a decrease in humidity. Given these trends, a decline in the profitability of growing some conventional crops can be predicted. To solve this problem, M. Prybuzkyi (2018) recommends selecting crops that are characterised by high drought resistance, productivity, and versatility of use.

L.O. Udova *et al.* (2014), following Stanford University researchers, point out that global warming will result in a decline in grain yields (specifically, wheat and barley) in European crop production over the next decades. By 2040, the figure is expected to decline by more than 20%. Maize is also expected to fall by at least 10%. Scientists argue that wheat and barley are more sensitive to rising temperatures in the face of climate change, while growing corn using irrigation technologies or using adapted varieties will reduce the negative impact of warming on crop productivity. According to R. Vignola *et al.* (2022), ecosystem-based adaptation (EbA) methods effectively address the problem of climate change in the cultivation of crops (maize, legumes, etc.). Optimisation goals can be achieved by building on the biodiversity of ecosystem resources and processes that may be available to farmers (e.g., the use of trees in agroforestry systems). FAO experts recommend active planting of forest strips to retain additional moisture, reduce the heating of the Earth's surface, preserve the fertile soil layer, etc.

There are also prospects for increasing maize production, subject to best agronomic practices. In countries experiencing climate change (USA, China, India), full-melt film water collection along ridge furrows is used. According to T.-l. Fan *et al.* (2023), the technology is a staple in maize cultivation in arid regions of many countries and is generally widely used to cope with hot climates.

Maize (as well as fodder beet) is a typical plant of the second group, which is characterised by resistance to hot temperatures. Under such conditions, they are more efficient in photosynthesis. In the context of climate change, which is accompanied by an increase in CO_2 concentration in the air, rising air, and soil temperatures, maize uses nitrogen more actively in photosynthesis. Scientific sources indicate that maize yields decline with increasing CO_2 concentrations in the atmosphere, but this is still more influenced by changes in the thermal regime. Up to a certain point, rising temperatures have a positive effect on maize productivity. Therefore, scientists predict an increase in the yield of this fodder crop when grown in Ukraine in the near future (To protect arable land in Ukraine..., 2021). In contrast, fodder beet is more sensitive to the amount of moisture in the air and soil. The need for it is especially high in March-April. A 10% change in soil moisture levels compared to optimal values causes a 20-25% decrease in fodder beet yields (Udova *et al.*, 2014). Therefore, the cultivation of this fodder crop must either be moved to the north or provided with an irrigation system.

In the context of climate warming, an essential area for the development of field fodder production is the increase in the sown area of fodder crops that are highly resistant to high temperatures and moisture deficit. Sorghum looks promising in this regard. Even in case of a severe drought, the crop does not perish, but only stops growing. After rainfall, the plant continues to grow. Due to its heat tolerance and resistance to drought, sorghum is grown on different continents: in India, the area under the crop reaches 12 million ha, in Africa – 21 million ha, and in the United States – 3.6 million ha (Prybuzkyi, 2018).

As a fodder crop, sorghum provides various types of fodder for farm animals. This includes grain, green fodder, silage, and hay. Accordingly, sorghum is considered an alternative to growing maize, which is traditionally the main silage crop for Ukrainian fodder production and a component of mixed fodder. Grain sorghum, sugar sorghum, and sorghum-sudangrass hybrid are used to feed livestock. Grain sorghum is used as a fodder, food, and industrial crop, and is included in fodder for pigs, cattle, poultry, and horses. The advantage of sorghum grain is its high nutritional value (nutritional value of 1 kg of grain is up to 1.3 fodder units). Its composition is as follows: up to 15% protein, up to 4.5% fat, up to 70% starch, up to 5% fibre, up to 2.5% lysine, and up to 1.9% methionine (Prybuzkyi, 2018). Considering these advantages of sorghum, Europe is implementing an action plan to promote this fodder crop. As a result, in 2018-2020, the area under sorghum in Europe increased, which led to an increase in its production. Although this figure declined in 2021-2022, in 2023 there was a trend towards an increase in the area under the crop again. In Ukraine, against the backdrop of the war, a negative trend is observed in 2022 (Fig. 4).

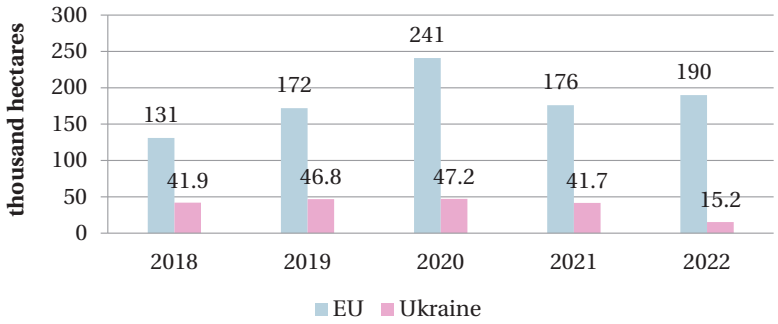

Figure 4. Sorghum planted areas and gross harvest in Europe and Ukraine in 2018-2022
Source: compiled by the authors of this study based on Productivity data. Sorghum is reliable (n.d.); USDA (2022); Agriculture, forestry, and fisheries (n.d.)

The development of fodder production in the context of climate change requires concrete optimisation measures that would offset the negative impact of external factors. At the same time, optimisation of agrotechnical measures can contribute to a more active use of the positive effects of climate change for field fodder production. This should also be considered, although most scientists focus only on the adaptation of agriculture to the negative factors of the climate crisis. Attention is also rarely paid to the opposite process – the risks of negative environmental impacts of fodder production. To minimise them, it is advisable to introduce energy efficiency measures, switch to renewable energy sources, improve the efficiency of waste recycling, etc. Globally and in Ukraine, such projects are promoted by governments, local authorities, and individual commercial entities. The activities of financial intermediaries that encourage investment in energy-saving technologies have a positive impact on the promotion of such measures in field fodder production. Ukrainian banks support environmental investment projects of agribusinesses by offering preferential lending rates, specifically under the government programme "Affordable Loans 5-7-9" (Strategy of the Ukraine's..., 2023). Thus, field fodder production is dependent on the climate crisis, and with proper practical functioning of this industry, adverse environmental consequences and impact on climate change can be minimised.

▸ Conclusions

The study made it possible to describe and systematise the mechanisms of climate change impact on field fodder production. Among the consequences of this impact are negative ones (reduced fertility and deterioration of soil conditions; reduced yields of fodder crops; increased activity of agricultural pests, increased frequency of diseases of fodder crops; frequent droughts and floods) and positive ones (longer growing season for fodder crops; shifting the growing zones for heat-loving fodder crops to the north; better conditions for wintering biennial and perennial fodder crops; increased yields of grain fodder crops due to the increase in carbon dioxide concentration in the atmosphere). The agrotechnical impact of climate change is mostly negative, but the economic consequences are manifested in an increase in demand for fodder crops, i.e., stimulating the development of field fodder production. The negative impacts will be counteracted by irrigation systems, growing new fodder crops or new varieties of already popular plants, using optimal crop rotations, planting forest belts, etc. Global experience shows the effectiveness of irrigated field fodder production, but in Ukraine the share of irrigated land is only 1.1%, while in Germany it is 9%, Moldova – 9.4%, Turkey – 13.7%, etc. Partial replacement of maize crops with drought-resistant sorghum is also promising in the face of climate change. In the EU, the area under this crop is about 200,000 ha, while in Ukraine, in the pre-war period, this figure exceeded 40,000 ha, but decreased considerably in 2022.

In turn, field fodder production also has a negative impact on the environment and climate. The mechanism of such impact can be direct (field destruction, waste pollution, etc.) and indirect (through livestock incentives). Therefore, the prospects for the development of fodder production in the new economic environment require not only adaptation to climate change, but also reduction of the industry's negative impact on the environment. Modern technologies for processing organic waste from field fodder production with a focus on energy production or high-performance compost, ways to reduce fuel consumption in fodder production, etc., the use of smart

technologies, and robotisation of the industry need to be investigated. The problems of financing measures to adapt fodder production to new climate conditions also require more in-depth research.

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▸ Conflict of Interest

The authors of this study declare no conflict of interest.

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Пріоритетні напрями розвитку польового кормовиробництва з урахуванням кліматичної кризи

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▸ **Анотація.** Стаття присвячена актуальній темі впливу кліматичних змін на сільське господарство України в цілому та на галузь польового кормовиробництва зокрема, а також проблемам адаптації сільського господарства до нових екологічних умов. Авторами було поставлено за мету обґрунтувати перспективні шляхи розвитку сучасного польового кормовиробництва з урахуванням кліматичних змін. Для цього використано абстрактно-логічний метод, системний аналіз, методи систематизації та класифікації, ряд економіко-статистичних методів дослідження (порівняння, ряди динаміки, метод структурних групувань). Було виділено як негативні, так і позитивні прояви кліматичної кризи у рослинництві, а також систематизовано можливі заходи протидії ризикам та шляхи використання потенційних можливостей розвитку польового кормовиробництва з урахуванням впливу змін клімату. Особливу увагу було звернено на світовий досвід ведення сільського господарства в умовах зміни клімату, зокрема, розглянуто складові системи «кліматично розумного»

рослинництва. Також у статті було охарактеризовано основні перспективні заходи адаптації польового кормовиробництва до кліматичних змін: зрошування сільськогосподарських земель, облаштування систем затримки снігу на полях, збору дощової води, селекцію та впровадження у практику нових сортів кормових культур, ефективні сівозміни, збільшення посівів посухостійких кормових культур, оптимізація агротехнологій з метою зменшення втрат кормових культур на етапах збирання врожаю та зберігання, застосування системи органічного землеробства, новітніх технологій удобрення ґрунтів, використання нанотехнологій обробітку ґрунтів. Результати проведеного дослідження можуть бути використані як менеджерами конкретних сільськогосподарських підприємств, так і дорадчими службами, державними органами в сфері реалізації аграрної політики

► **Ключові слова:** кормові культури; кліматичні зміни; зрошування; органічне землеробство; сорго

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Assessment of the level of competitiveness of Ukrainian agricultural holdings in international markets

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► **Abstract.** Agriculture remains one of the main sectors that play an important role in both the country's economic development and strategic security. Therefore, conducting an ongoing study of this component in the country is relevant. The purpose of the study was to determine the competitive opportunities of agricultural holdings in Ukraine. The methods of scientific cognition that were used in the work were abstract and logical, dialectical, general scientific and statistical methods, methods of historical and logical observation, analysis and synthesis. This study analyses the competitiveness of Ukrainian agricultural production, in particular by such indicators as: dynamics of gross harvest, yield and acreage of the main agricultural crops, balance of agricultural production, export of agricultural products and their processed products during 2000-2023. The methods that need to be implemented to make the agro-industrial complex competitive in the global market are also proposed. The results of this research on the competitiveness of Ukrainian agricultural holdings in international markets, and the conclusions drawn on their basis, are of significant importance, as they prove that powerful agricultural holdings operate in Ukraine, characterised by dynamic capabilities, increase their capacities, attract unused arable land, and effectively use the potential of resources and crops. In addition, the development of world markets for agricultural products is promising for agricultural holdings, because Ukraine is geographically located almost in the centre of international trade networks, and exports in some strategic areas will help agricultural enterprises avoid uncertainty and possible large losses. The assessment of agricultural holdings, namely Kernel and Myronivsky Hlibprodukt, showed that even in war conditions, agricultural companies have opportunities to develop and enter international markets. The findings obtained in the framework of the study can be used both by representatives of the public sector to form policies in this area, and by enterprises to create long-term development strategies

► **Keywords:** agriculture; competition; production; sales markets; export

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▸ Introduction

Market integration processes in agriculture are implemented through the establishment and development of various types of integration structures (Hou *et al.*, 2017). However, the experience of developing integration structures in the field of agro-industrial complex (AIC) in different countries indicates that the creation of agricultural holdings is an effective way for the functioning of forms of agro-industrial integration. Since 2000, they have become a significant phenomenon in the field of agriculture in Ukraine. These agricultural companies are organised with centralised management and consist of several enterprises. According to the Economic Code of Ukraine (2003), a holding company is defined as a public joint-stock company that owns, uses and manages holding blocks of shares in two or more corporate companies. Thus, not all companies in the agricultural sector have the official status of agricultural holdings from a legal standpoint, but in practice they are considered agricultural holdings.

Agricultural holdings in Ukraine mainly specialise in the production of agricultural products. Livestock plays a small role, with the exception of poultry. Target production of cereals and oilseeds in export markets, while other products are mainly for the companies' own processing facilities (Nedilska, 2019; Danko *et al.,* 2020). A. Zadoia (2016) also focuses on the scale and geographical structure of Ukraine's foreign economic activity, noting that they reflect the reorientation of exports and imports to more developed markets. Such researchers as N. Patyka (2018) also investigated the issues of determining competitiveness, however, the assessment of the competitiveness of Ukrainian agricultural holdings, considering their participation in foreign economic activity, remains insufficiently studied. Special attention is paid to the competitiveness of agricultural enterprises related to the cultivation and sale of agricultural products. The main goal of modern agricultural holdings is to achieve competitive advantages in the long term, to obtain a high rate of profit and sustainable economic growth (Trivić, 2020; Grzelak, 2022). That is why the primary task is to maintain existing market positions and find new opportunities to expand sales markets and increase economic efficiency.

In search of development, agricultural firms are forced to enter foreign markets, where competition is much higher than within the country. Therefore, for the implementation of effective foreign economic activity, a single strategic development plan is extremely important for the enterprise, which will ensure the achievement of competitive advantages. The assessment of the competitiveness of agricultural holdings should be carried out according to a set of criteria, namely: capacity volumes, production level, exports. Mainly, competition in the EU agricultural market is caused by a large number of relatively undifferentiated players. In general, such competition should be assessed as strong, and the success of entering the global market of new participants depends on a number of factors, while costs on a large scale can be unaffordable and the chances of success can be justified if there is a quality product.

As noted by Y. Syta (2019), competitiveness is the ability to leverage strengths and focus efforts in areas where it is possible to take a leading position in the markets. Considering foreign markets, this will characterise international competitiveness. A. Zalievska-Shyshak & Yu. Fesun (2021) studied the role of agricultural holdings in introducing innovations in the agricultural sector of the Ukrainian economy. They noted that these companies are now one of the main drivers of innovation in the country, as they provide opportunities and resources (including financial ones) for implementing the latest technologies. However, it should be understood that in war conditions, such opportunities become limited. The innovation component of the agricultural sector was also investigated by T. Sus *et al.* (2023). Researchers pointed to the fact that the agricultural sector of Ukraine has problems in financing innovative development. However, they did not pay attention to the factors of war and their impact on the development opportunities of the industry, and also did not provide practical advice on solving these problems. O. Drahan & V. Zubchenko (2023), in turn, drew conclusions about the possibilities of functioning of agricultural holding companies in Ukraine: they proposed areas for the development of such enterprises by the state, but did it quite superficially. In addition, they did not assess the war factor as part of the analysis.

Thus, the analysis of academic publications shows that currently the results on the competitiveness of agricultural holdings are quite limited and uncertain, there is a need for a broader analysis of the activities and production processes of Ukrainian agricultural holdings, which adds relevance to the study. The international competitiveness of the agricultural holding indicates efficient production activities in the conditions of world markets. The viability of the enterprise, the ability to effectively use financial, production, labour, scientific and technical potentials characterise the production and sale of services and goods. Considering the above, the development and implementation of competition strategies is a top management priority. The company's success in the Ukrainian and international markets will depend on how well the strategy is chosen.

The purpose of the study was to determine the competitive advantages of agricultural holdings in Ukraine. To achieve this goal, the main research objectives are highlighted:

– determine the competitive advantages and disadvantages of agricultural holdings in Ukraine in production;

– identify the factors influencing the competitiveness of agricultural holdings;

– investigate possible future adaptations of organisational forms to maintain or increase their competitiveness.

▸ Materials and Methods

The study used separate materials on international agreements that characterised the interaction between Ukraine and other countries in the context of international trade in agricultural products. In particular, information from the Association Agreement (n.d.) between Ukraine and the EU and the EU-Ukraine deep and comprehensive free trade area (2021) was used.

The source that allowed evaluating data on the export of agricultural products to Ukraine was the website TradeMap, which specialises in collecting such information for countries (List of importing markets…, n.d.). In addition, the source provides information in the context

of types of products, services, countries, which allows for a more detailed assessment. The study used data from the state statistics service, which became the main source of statistical data in the study. In particular, this service provided information on the area planted with agricultural products, gross harvest, yield, and net profit of enterprises. It is also worth paying attention to the fact that the level of net profit of enterprises was estimated considering inflation to assess the real growth rate of profitability of companies. Indicators regarding the level of depreciation of the national currency in Ukraine were taken from the Ukraine: Inflation rate from 2003 to 2028 (n.d.). In addition, significant amounts of data describing the development of the agricultural sector in Ukraine are still not available as of 2023. In this regard, only information up to 2022 was used in the study. The exception is statistics on agricultural exports. Data for 2023 is available for the first 3 quarters. Thus, the forecast value for 2023 was calculated using the equation:

$$Y = \frac{(Q_1+Q_2+Q_3)}{3} \times 4, \quad (1)$$

where Y – data for the year; Q_1 – data for the corresponding quarter since the beginning of 2023.

Although this estimate is quite approximate, it allows drawing some conclusions about the dynamics of exports as of 2023 with an accuracy of about 75%. However, future studies may require additional evaluation of these values based on definitively provided verified data sources. All constructions and calculations were performed in Microsoft Excel.

Financial results data for agricultural holdings Kernel and Myronivsky Hlibprodukt (MHP) were taken from Annual reports (n.d.) and Financial Reports (n.d.) respectively. To achieve this goal, the study used the dialectical method of scientific cognition, general scientific and special methods. Statistical analysis was used when analysing the current state of the agricultural sector and evaluating methods of its development: the method of average and relative values, trend analysis, index method, coefficient analysis, and comparative analysis to assess the results obtained over different years. To generalise the scientific and methodological nature, the abstract and logical method of the approach to studying the competitiveness of Ukrainian agricultural holdings and the formulation of conclusions were used. In addition, the study used methods of historical and logical observation, analysis and synthesis. The method of economic and statistical research was used to analyse international statistics on the export of agricultural products. The generalisation was used to summarise the results of the study.

▸ Results

Ukrainian agricultural holdings differ in how they were created, namely with the help of: investments of processors; growth of farms; investments of financial and industrial companies. The first group includes agricultural holdings that have emerged from investments by agricultural commodity processors. In addition to purely profitability considerations, their main goal was to ensure supply. The next group of agricultural holdings consists of those that emerged from successful farming and grew beyond their single operation. For this purpose, companies that attracted external investors or other sources of financing were usually included. The third group of agricultural holdings is the result of domestic or international external investments, for example, by banks, industrial companies, or investment funds. Previously, such investors were not part of the agricultural sector. This includes some of the largest agricultural holdings in terms of arable land area. The motives are mainly profit-making opportunities, with the view of agriculture as a sector with a promising future (Syta, 2019). For any agricultural holding, sooner or later the task of entering the international market may arise. The products produced must be competitive compared to foreign producers (Thorne *et al.*, 2017; Dankevych *et al.*, 2022).

Agriculture is a very priority sector for Ukraine, especially in the context of the signing of the Association Agreement (n.d.) between Ukraine and the European Union (EU) and the implementation of the EU-Ukraine deep and comprehensive free trade area (2021). Data on how this affected the export of agricultural products in Ukraine can be seen in Table 1.

Table 1. Data on the export of agricultural products and their largest components in Ukraine in the period from 2019 to 2023, billion USD

Years	2019	2020	2021	2022	2023*
All products	50.1	49.2	68.1	44.4	36.2
Agricultural products	22.2	22.2	27.8	23.7	21.6
Unrefined sunflower or safflower oil	3.8	4.7	5.7	4.7	4.3
Seeds of rapeseed or low erucic acid rapeseed "yielding a non-volatile oil with an erucic acid content of <2% and containing a solid component of glucosinolates <30 micromol/g", whether crushed or uncrushed (except seeds for sowing)	1.3	1	1.7	1.4	0.9
Wheat and meslin (except seeds for sowing and durum wheat)	3.7	3.6	5.1	2.6	3
Corn (except seeds for sowing)	5.2	4.9	5.9	5.9	5.1

Note: * – the value for 2023 was calculated based on information for 3 quarters using Equation 1
Source: compiled by the authors based on List of importing markets for a product exported by Ukraine (n.d.)

As can be seen from Table 1, the volume of exports from Ukraine, in particular – in the context of agricultural products, grew in the period from 2019 to 2021, which may be due to the strengthening of the country's integration with the European Union, and with the beginning of the COVID-19 pandemic, which led to an increase in prices

for certain types of products, in particular, the agricultural sector. In 2022 and 2023, there was a gradual decline in export volumes, which was associated with the beginning of a full-scale Russian invasion of Ukraine and the corresponding negative consequences that it led to.

As a result of the study, it was established that during 2000-2022 in Ukraine there was a clear trend of increasing the dynamics of the gross harvest of the main agricultural crops, in particular: cereals and legumes, sunflower, rapeseed and open-ground vegetable crops. This gives grounds to assert that for two decades Ukrainian producers of agricultural products have been gaining momentum, and the gross yield capacity in relation to 2000 reaches 150-200%. As for the yield of the main agricultural crops, all crops showed an increase in yield opportunities compared to 2000. Similarly, there was an increase in the area under crops, except for potatoes and open-grown vegetables. It is also worth considering some indicators that characterise the natural volume of agricultural development in Ukraine. So, data on the volume of planted products can be seen in Table 2.

Table 2. Volumes of planted vegetation production in Ukraine in the period from 2000 to 2022, in hectares

Indicator	Grain and leguminous crops	Industrial sugar beet	Sunflower	Potatoes	Vegetable crops	Fruit and berry crops
2000	19.4	177	12.2	122	112	38.4
2001	27.1	183	9.4	108	123	30.5
2002	27.3	189	12	104	124	36.5
2003	18.2	201	11.2	116	139	56.0
2004	28.3	238	8.9	133	149	58.1
2005	26	248	12.8	128	157	63.7
2006	24.1	285	13.6	133	171	45
2007	21.8	294	12.2	131	152	61.7
2008	34.6	356	15.3	139	174	64.4
2009	29.8	315	15.2	139	183	70.7
2010	26.9	279	15	132	174	78.2
2011	37	363	18.4	168	195	84.9
2012	31.2	411	16.5	161	199	89.9
2013	39.9	399	21.7	160	200	103.5
2014*	43.7	477	19.4	176	208	95.2
2015*	41.1	436	21.6	161	206	104.5
2016*	46.1	482	22.4	166	211	101.9
2017*	42.5	475	20.2	168	208	103.1
2018*	47.4	509	23	171	214	128.4
2019*	49.1	461	25.6	155	214	108.1
2020*	42.5	416	20.2	157	207	105.6
2021*	53.9	479	24.6	166	215	117.3
2022**	45.8	541	21.6	174	200	116.1
Change	26.4 (136.1%)	364 (205.6%)	9.4 (77%)	52 (42.6%)	88 (78.6%)	77.7 (202.3%)

Note: * – the value was calculated without considering the temporarily occupied territories after the Russian aggression in 2014; ** – the value was calculated without considering the territories that were occupied as a result of the full-scale Russian invasion of Ukraine in 2022

Source: compiled by the authors based on Economic statistics/Economic activity/Agriculture, forestry, and fisheries (n.d.)

It is also important to emphasise that according to the Ministry of Agrarian Policy and Food of Ukraine, as of 2020, about 462 thousand hectares of agricultural land were registered in Ukraine for organic production. This, in turn, accounts for 1.1% of the total area of agricultural land in Ukraine. Moreover, since 2010, the amount of agricultural land allocated for organic production has been growing. This trend is in line with the demand for eco-products in the world, so it can be one of the aspects of ensuring competition for Ukrainian agricultural holdings in the world market (Organic production in Ukraine, n.d.). Thus, despite the negative trends associated with the loss of territories after 2014, the volume of sown products in Ukraine is growing, which is a positive trend in general. The decline occurred only in 2022 for certain types, which is associated with the beginning of a full-scale Russian invasion of Ukraine. It is also worth considering the production volumes shown in Table 3.

Table 3. Gross harvest of vegetation products in Ukraine in the period from 2000 to 2022, in thousand tonnes

Indicator	Grain and leguminous crops	Industrial sugar beet	Sunflower	Potatoes	Vegetable crops	Fruit and berry crops
2000	24,459	13,199	3,457	19,838	5,821	1,453
2001	39,706	15,575	2,251	17,344	5,907	1,106
2002	38,804	14,452	3,271	16,619	5,827	1,211
2003	20,234	13,392	4,254	18,453	6,538	1,697
2004	41,809	16,6	3,05	20,755	6,964	1,635
2005	38,016	15,468	4,706	19,462	7,295	1,69
2006	34,258	22,421	5,324	19,467	8,058	1,114
2007	29,295	16,978	4,174	19,102	6,835	1,47
2008	53,29	13,438	6,526	19,545	7,965	1,504
2009	46,028	10,068	6,364	19,666	8,341	1,618
2010	39,271	13,749	6,772	18,705	8,122	1,747
2011	56,747	18,74	8,671	24,248	9,833	1,896
2012	46,216	18,439	8,387	23,250	10,017	2,009
2013	63,051	10,789	11,051	22,259	9,873	2,295
2014*	63,859	15,734	10,134	23,693	9,638	1,999
2015*	60,126	10,331	11,181	20,839	9,214	2,153
2016*	66,088	14,011	13,627	21,75	9,415	2,007
2017*	61,917	14,882	12,236	22,208	9,286	2,048
2018*	70,057	13,968	14,165	22,504	9,44	2,571
2019*	75,143	10,205	15,254	20,269	9,688	2,119
2020*	64,933	9,15	13,11	20,838	9,653	2,024
2021*	86,01	10,854	16,392	21,356	9,935	2,235
2022**	53,864	9,942	11,329	20,9	7,512	1,995
Change	29.405 (120.2%)	-3.257 (-24.7%)	7.872 (227.7%)	1.062 (5.4%)	1.691 (29%)	542 (37.3%)

Note: * – the value was calculated without considering the temporarily occupied territories after the Russian aggression in 2014; ** – the value was calculated without considering the territories that were occupied as a result of the full-scale Russian invasion of Ukraine in 2022

Source: compiled by the authors based on Economic statistics/Economic activity/Agriculture, forestry, and fisheries (n.d.)

As can be seen from Table 3, the volume of harvesting of most types of products has increased: the only exception is sugar beet, which is primarily due to the lower possibility for competition of this type of product in comparison with sugar cane on the world market. Thus, such trends indicate generally positive trends in the development of agricultural products in Ukraine. An important indicator is also the yield, data on which can be seen in Table 4.

Table 4. Data on the yield of certain types of agricultural products in Ukraine in the period from 2000 to 2022, in dt from 1 hectare of harvested area

Indicator	Grain and leguminous crops	Industrial sugar beet	Sunflower	Potatoes	Vegetable crops	Fruit and berry crops
2000	19.4	177	12.2	122	112	38.4
2001	27.1	183	9.4	108	123	30.5
2002	27.3	189	12	104	124	36.5
2003	18.2	201	11.2	116	139	56
2004	28.3	238	8.9	133	149	58.1
2005	26	248	12.8	128	157	63.7
2006	24.1	285	13.6	133	171	45
2007	21.8	294	12.2	131	152	61.7
2008	34.6	356	15.3	139	174	64.4
2009	29.8	315	15.2	139	183	70.7
2010	26.9	279	15	132	174	78.2

Table 4, Continued

Indicator	Grain and leguminous crops	Industrial sugar beet	Sunflower	Potatoes	Vegetable crops	Fruit and berry crops
2011	37	363	18.4	168	195	84.9
2012	31.2	411	16.5	161	199	89.9
2013	39.9	399	21.7	160	200	103.5
2014*	43.7	477	19.4	176	208	95.2
2015*	41.1	436	21.6	161	206	104.5
2016*	46.1	482	22.4	166	211	101.9
2017*	42.5	475	20.2	168	208	103.1
2018*	47.4	509	23	171	214	128.4
2019*	49.1	461	25.6	155	214	108.1
2020*	42.5	416	20.2	157	207	105.6
2021*	53.9	479	24.6	166	215	117.3
2022**	45.8	541	21.6	174	200	116.1
Change	26.4 (136.1%)	364 (205.6%)	9.4 (77%)	52 (42.6%)	88 (78.6%)	77.7 (202.3%)

Note: * – the value was calculated without considering the temporarily occupied territories after the Russian aggression in 2014; ** – the value was calculated without considering the territories that were occupied as a result of the full-scale Russian invasion of Ukraine in 2022
Source: compiled by the authors based on Economic statistics/Economic activity/Agriculture, forestry, and fisheries (n.d.)

As can be seen from Table 4, the level of yield of all types of products has increased significantly, which may indicate that the country has begun to use generally better technologies that allow obtaining more yield per unit of production. This indicates, first of all, positive trends in the development of agriculture in Ukraine. It is also worth assessing the level of profitability of agricultural enterprises in Ukraine, data on which are shown in Table 5.

Table 5. Net profit level of large, medium, small, and microenterprises in Ukraine in the period from 2010 to 2022, adjusted for inflation (in 2010 prices), in billion UAH

Type of enterprise	Large	Medium	Small	Micro
2010	2.612	12.319	2.24	0.102
2011	3.366	13.171	6.937	1.881
2012	4.886	12.594	7.194	1.728
2013	3.526	6.414	3.898	0.98
2014*	4.303	7.72	5.674	1.135
2015*	13.734	24.362	18.892	5.151
2016*	5.879	20.828	17.371	4.909
2017*	3.427	15.058	10.784	1.72
2018*	4.297	14.743	8.161	1.886
2019*	1.785	24.311	7.019	2.071
2020*	2.999	13.936	11.274	3.714
2021*	15.256	32.358	27.857	7.939
2022**	4.775	10.439	7.416	1.702
Change	2.2 (82.8%)	-1.9 (-15.3%)	5.2 (231%)	1.6 (1565.4%)

Note: * – the value was calculated without considering the temporarily occupied territories after the Russian aggression in 2014; ** – the value was calculated without considering the territories that were occupied as a result of the full-scale Russian invasion of Ukraine in 2022
Source: compiled by the authors based on Economic statistics/Economic activity/Agriculture, forestry, and fisheries (n.d.)

As can be seen from Table 5, the profitability of many types of companies, despite the negative trends in the economy, remained higher than as of 2010. Only medium-sized enterprises receive lower returns. It is also worth noting that the profitability of companies in 2021 was even higher for many companies. In addition to analysing the competitiveness of agricultural producers, it is worth suggesting possible ways to improve it. In particular, at the national level, the management of agro-industrial production is the introduction of a strategy for

entering new markets for products by establishing relations with foreign countries and strengthening existing ones, and the development of a certification system for organic products in accordance with international standards, since the production of organic products is quite promising in the country. As for the subjects of agricultural production – this is an increase in the production and export of goods that are leaders in world trade, and intensive cultivation of niche crops. In addition, there is a need to increase the efficiency of logistics processes, build additional granaries, reduce the cost of production and improve quality indicators, and the growth of trends in the greater spread of e-commerce in the agricultural sector. Thus, the dynamic growth of the global market of agricultural products and their processed products determines promising areas of development of agricultural holdings and creates conditions for increasing exports of products (Tse *et al.*, 2017).

Export of products and raw materials is also an important indicator of competitiveness (Shikovets *et al.*, 2020). The active expansion of the presence of Ukrainian producers on world markets is an important component of the development of Ukrainian exports, which opens up huge opportunities both for the domestic producer, which receives more revenue from the added value of finished products, and for the national economy – after all, increasing the export of finished products contributes to the development of the food industry in the country, attracts investment in this and related industries and creates new jobs. The main agricultural holdings in Ukraine remain Kernel and MHP, which are among the largest agricultural companies in Ukraine. Considering the Kernel company, the main goal of strategic management is to create a dynamic management system that ensures high competitiveness of the enterprise, in particular, by obtaining benefits from further integration of the country into the European Union. The impact of European integration extends to strategic governance through considerations such as European values, legal standards, EU-compliant reforms, and market opportunities in EU countries. For each export activity of the company (sunflower oil, niche and traditional cereals), the company develops individual development strategies.

Kernel faced challenges during the war, focusing on strategic planning, liquidity, and sustainability. The company coped with the temporary shutdown of Black Sea ports by strengthening decentralisation, receiving help from the army and finding new export channels. Business strategies have been adapted by changing crop rotation and reducing dependence on certain crops. Kernel managed banking risks through diversification and even transferred some of its liquidity to cryptocurrency. Communication with stakeholders, including creditors and investors, remained transparent, and two planning scenarios were considered. The need for reforms to support the economic recovery was highlighted, and the company's future plans include stockpiling, export diversification, and exploring recycling options and environmental energy projects. The company's financial results for recent years can be seen in Table 6.

Table 6. Data on Kernel's financial results for the period from 2017 to 2023

Year	2017	2018	2019	2020	2021	2022	2023
Profit, billion USD	2.17	2.4	3.99	4.11	5.65	5.33	3.46
Net financial result, billion USD	0.5	0.2	0.25	0.7	0.83	0.19	-0.3
Assets, billion USD	2.01	2.21	2.46	3.16	4	4.19	3.89
Coverage ratio	3.81	2.16	1.97	3.71	2.92	1.13	1.29
Quick liquidity ratio	2.5	1.5	1.91	2.98	2.49	0.7	1.11
Absolute liquidity ratio	0.49	0.24	0.12	0.89	0.73	0.2	0.5

Note: Kernel submits financial statements for the period from June to June; in this regard, the financial statements for 2023 are already completed (this method of reporting affected the reflection of the impact of the outbreak of war in Ukraine in 2022, which was relatively insignificant in the financial statements)
Source: compiled by the authors based on data from Annual reports (n.d.)

As can be seen from Table 6, the company's profit grew until 2022, which is conditioned by the beginning of the war in Ukraine. The same can be said about the net financial result, which from 2018 showed growth until 2022, and the volume of assets. Considering the liquidity ratios, they were also at quite high levels: for example, for the coverage ratio, a value greater than 1 is acceptable and fast liquidity, and absolute liquidity is 0.2-0.25. As can be seen from the data in Table 6, even after the outbreak of the war in 2022, liquidity indicators generally remained satisfactory, which may indicate a significant financial stability of the company. However, there was a rapid decline in financial stability indicators, a drop in profits and a negative financial result: in the event of a prolonged war and the continuation of such trends, there is a risk of problems in the company. Given that it is one of the main ones for the country's agricultural sector, state assistance may be required to support it (Katsylo, 2022).

The company is active in achieving sustainable development goals in various fields, focusing on energy management, water management, maximum waste reduction, and biodiversity protection (Annual reports, n.d.). The company's efforts are focused on improving the efficiency of its own operations, reducing greenhouse gas emissions and generating electricity from biomass. Water and wastewater management involves rational water consumption, strict pollution prevention measures, and investment in technologies such as dry cooling systems. Waste management, in turn, consists in reducing it, properly processing it, and strictly controlling its generation. In biodiversity management, Kernel uses IT solutions for data processing, which allows monitoring

of surrounding areas and avoiding activities in areas with high biodiversity. This approach highlights the company's desire to achieve the principles of sustainable development, minimising the impact on the environment, improving energy efficiency and preserving biodiversity as part of its activities.

MHP, in turn, planned to carry out a complete transformation of the business, including improving customer service and creating a new franchise model. They considered ensuring people's well-being to be the basis of their strategy. The company continues to deepen its own investment processes in foreign companies, trying to expand its influence in foreign markets. Among its goals are to increase production volumes, optimise the cultivation of grain crops and increase exports through geographical diversification. MHP is committed to sustainable development, reducing greenhouse gas emissions, and achieving a carbon-neutral footprint. Despite the impact of the conflict, MHP continued its business transformation, focusing on value-added products and food security. The war led to a short pause in the production of some goods, but MHP quickly resumed and introduced new products. The company still remains focused on customer orientation and tries to adapt to the needs of consumers. It is worth considering individual financial indicators and MHP companies. They are shown in Table 7.

Table 7. MHP's financial performance for the period from 2017 to 2023

Year	2017	2018	2019	2020	2021	2022	Q3 2023
Profit, billion USD	1.29	1.56	2.06	1.91	2.37	2.64	2.29
Net financial result, billion USD	0.36	0.19	0.59	-0.03	0.61	-0.03	0.12
Assets, billion USD	2.28	2.67	3.69	3.28	4.1	3.81	3.93
Coverage ratio	5.26	3.25	3.03	3.13	3.13	2.92	1.63
Quick liquidity ratio	3.78	2.39	2.49	2.49	2.43	2.84	1.35
Absolute liquidity ratio	0.82	0.66	0.87	0.58	0.52	0.56	0.45

Note: data for 2023 is only available for the first 3 quarters
Source: compiled by the authors based on Financial Reports (n.d.)

As can be seen from Table 7, the company's profit is growing despite the outbreak of war in Ukraine. The company also showed minor losses in 2022, as in 2020, which is due to a full-scale invasion and the beginning of the COVID-19 crisis, respectively, but these values were close to 0, which indicates the company's significant resilience to global crises. This is also indicated by the growth of assets until 2022 and only a slight decrease in it in subsequent years, and high liquidity indicators, which even during the war remain significantly higher than normal. MHP showed a relatively higher level of financial stability compared to Kernel. However, it is still difficult to assess what the future impact of the war will be on the company, and whether it will need state assistance in the future. MHP is also focused on sustainable development: it promotes its own activities to achieve the UN Sustainable Development Goals (SDGs), working with Ukrainian stakeholders (other businesses, the state and citizens in general) to improve infrastructure, education, health, and economic opportunities in the country and in the regions. The company prioritises health and well-being, an example of which was the company's response to the outbreak of the COVID-19 crisis, which was aimed at supporting the well-being and health of employees. MHP also supports measures for inclusive education, gender equality, access to clean water and affordable clean energy. It encourages economic growth and infrastructure development. One of its most important projects is the development of biogas plants to move away from traditional energy sources and give preference to renewable ones. Thus, the largest agricultural holdings in Ukraine had certain problems associated with the beginning of a full-scale invasion, but they are coping with the challenges that have arisen. In addition, both companies continue their activities aimed at achieving the sustainable development goals. The state authorities, in turn, are interested in ensuring that these companies can successfully cope with the problems associated with a full-scale invasion. Therefore, in case of difficulties, a company should be ready to provide assistance to these and other enterprises of the agricultural sector to ensure that they can continue to conduct their activities.

Discussion

The strategy of gradual distribution of Ukrainian agricultural products to other markets is really promising for the country's agricultural holdings. Exports in key strategic areas can help rural businesses overcome insignificance and potential surpluses. Processing enterprises in the agricultural sector should focus not only on the EU markets, but also on global ones. This approach should encourage agricultural producers to expand their capabilities and comply with international norms and standards, emphasising the need for government support and investment in infrastructure, logistics and marketing. To strengthen Ukraine's competitive position, it is still important to develop a certification system for organic products that meets international standards, increase efforts in crop cultivation, and find methods to improve product quality and yield. In addition, logistics optimisation and cooperation with state authorities remain an important component.

The results of this research on the competitiveness of Ukrainian agricultural holdings in international markets, and the conclusions drawn on their basis, are of significant importance, as they prove that powerful agricultural holdings operate in Ukraine, characterised by dynamic capabilities, increase their capacities, attract unused arable land, and effectively use the potential of resources and crops. In addition, the development of world markets for agricultural products is promising for agricultural holdings, because Ukraine is geographically located almost

in the centre of international retail chains. Summing up the above, consideration of the innovation factor should be one of the crucial conditions for the further development of agricultural holdings in the near future. Active state support should also function to establish partnerships between state structures and the private sector of the economy, which will ensure the competitiveness of agricultural holdings, including in foreign markets. In order for Ukraine to become a competitive player in the global market of finished food products and finally get rid of the label of "raw material appendage", producers need to solve a number of complex problems. The analysis of the activity of Ukrainian agricultural holdings indicates that in recent years there have been optimistic indicators of their competitive activity, in particular: the dynamics of gross harvest, yield and acreage of niche crops, the balance of agricultural production, the export of agricultural products and their processed products, and a number of promising areas of agricultural production and competitive strategies that ensure Ukraine's access to world markets. Nevertheless, due to the beginning of a full-scale Russian invasion of Ukraine, the deterioration of the situation in the country as a whole, and in particular for agricultural holdings, has become noticeable. Thus, the state authorities should support these companies in order to ensure their development even in the difficult conditions in which the country is located (Yevtushenko *et al.*, 2022).

Analysing the situation in Ukraine, it can be noted that large and medium-sized agricultural holdings have become the main productive force in the agricultural sector of the economy. According to industry studies based on information from individual companies, large agricultural enterprises currently lease more than 3.5 million hectares of land, or 10.8% of all arable land and 20% of leased arable land, while the smallest companies in this group control more than 30 thousand hectares each (Dankevych *et al.*, 2022). The issue of assessing the competitiveness of agricultural holdings has been considered repeatedly both in individual papers and in fundamental scientific studies, but a unified methodology for assessing the competitiveness of an industrial enterprise has not been developed, and the issue of competitiveness of Ukrainian agricultural holdings in world markets remains rather neglected. However, there are some common aspects in the methodological approaches of the researchers and this study in particular. According to Y. Syta (2019), it is necessary to consider comprehensive methods for assessing the competitiveness of enterprises focused on analysing the entire range of parameters of enterprise functioning. V. Byba (2017) and Y. Karpyshyn (2017) also emphasised that most enterprises of the agricultural sector of the Ukrainian economy are provided with sufficient prerequisites for successful entry into the world community, among which the main one is a large natural resource and human potential, but state incentives and support for this industry are important (Vernihorova, 2021).

The influence of agricultural holdings on rural development was studied on the example of Romania. R.V. Ionescu *et al.* (2021) emphasised the importance of state financial support as a crucial tool for agricultural holding companies, emphasising the need for targeted measures to ensure the availability and successful functioning of business entities. As part of the study, it was shown that agricultural holdings really play an important role in the development of rural areas. However, the researchers also provided separate recommendations on this issue, aimed primarily at improving the legislative framework, implementing specific measures of economic incentives, strengthening strategic cooperation outside of state bodies, and promoting transparency of consistent agricultural policy. The study of agricultural holdings in Ukraine did not pay such attention to the analysis of their role for rural development, but it is worth noting that it is actually significant. Thus, with the help of such companies, a significant number of jobs are created, and an appropriate infrastructure is created that contributes to the development of the village. Thus, the support of such companies can be important for the state to promote rural development (Zakharchenko, 2017).

The functioning of agricultural holdings in the Czech Republic, in turn, was considered by Z.Hloušková *et al.* (2022). Researchers have shown that large holdings in a country tend to have higher economic returns and financial stability, while small companies face greater challenges of economic viability. There is even a possibility that individual companies may go bankrupt in the near future. In this regard, researchers note the importance of state support measures for such companies. The study of agricultural holdings in Ukraine also noted the need to support companies in the agricultural sector. The difference is that in the Czech Republic, only small companies need such support, while in Ukraine – everything that is associated with the difficulties associated with a full-scale invasion of Russia. The main difficulty, however, is that the state spends significant amounts of resources on military needs, and therefore, must pay less attention to other components, such as supporting businesses, ensuring the social needs of citizens. Nevertheless, it must make every effort to fulfil all its obligations to society as much as possible (Vernihorova, 2021).

Separate conclusions on the development of Agriculture on the example of Poland were also drawn by J. Kulawik *et al.* (2020). The researchers noted that agricultural support systems play a crucial role in stabilising farm incomes, making farms dependent on the decisions of individual countries and the EU as an association. In this regard, they become vulnerable to external shocks. Thus, researchers propose to create a common agricultural policy that will allow the sector to adequately develop and make it able to more effectively resist external crises. As noted in the study on agricultural holdings in Ukraine, the implementation of a high-quality policy in the field of agriculture is really an important component for the development of the sector. However, it should be understood that support for this area should be at such a level that it does not completely kill competition for Ukrainian producers, and leave them incentives for development. Only in this way can a sufficient level of agricultural sustainability be achieved in the country.

▸ Conclusions

One of the successful factors in Ukraine's agro-industrial integration is the creation of agricultural holdings. The share of the agro-industrial sector in the national GDP

depends on a number of factors, in particular: natural and climatic conditions, access to sales markets, specialisation. The level of development of the agricultural and industrial complex is significantly influenced by the national policy that regulates foreign markets and can focus on increasing the competitiveness of its own agricultural sector and ensure the growth of export positions of agricultural products in the EU market.

In the period from 2000 to 2021, Ukraine recorded a positive and progressive balance of production for almost all types of agricultural products, with the main crops, such as cereals, legumes, sunflower, rapeseed, and open-ground vegetables, there is a clear trend of increasing the dynamics of gross harvest. This shows that Ukrainian producers of agricultural products have been increasing production volumes for two decades, which contributes to increasing competitiveness. In relation to the yield of agricultural crops, an increase in their capabilities was recorded compared to 2000. There was also an increase in the area under agricultural crops, with the exception of some vegetable crops and potatoes. Even in the sector of niche agricultural products, dynamics were noted, which indicates the active development of agricultural holdings, their expansion and efficient use of resources and land areas. During the war, agricultural holdings as a whole continued their activities aimed at developing their own products abroad. However, military action will significantly suspend the development opportunities of such companies. That is why in modern conditions they need more than usual support from the state.

As a result of the study, it was found that the gradual development of world markets for agricultural products is very promising for agricultural holdings, because Ukraine is geographically located almost in the centre of international retail chains. Exports in some strategic areas will help agricultural enterprises avoid uncertainty and possible large losses. The study also indicates that Ukrainian agricultural holdings have a huge potential for developing exports of products, but this requires the state's interest in quickly solving emerging problems and the operational ability to respond to the changing needs of the world market. In further research, it is important to analyse the issue of increasing the investment attractiveness of the agro-industrial complex of Ukraine, analysing in recent years all possible risks associated with the investment climate, and optimise the search for ways to reduce import dependence.

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Conflict of Interest

The authors of this study declare no conflict of interest.

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Оцінка рівня конкурентоспроможності українських агрохолдингів на міжнародних ринках

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► **Анотація.** Сільське господарство залишається однією з основних галузей, які відіграють важливу роль як в економічному розвитку країни, так і в стратегічній безпеці. Тому проведення в країні постійного дослідження цієї складової є актуальним. Метою дослідження було визначення конкурентних можливостей агрохолдингів України. Методами наукового пізнання, які були використані в роботі, були абстрактно-логічний, діалектичний, загальнонауковий та статистичний методи, методи історико-логічного спостереження, аналізу та синтезу. У даному дослідженні проаналізовано конкурентоспроможність сільськогосподарського виробництва України, зокрема за такими показниками як: динаміка валового збору, урожайності та площі основних сільськогосподарських культур, баланс сільськогосподарського виробництва, експорт сільськогосподарської продукції та продуктів її переробки протягом 2000-2023 років. Запропоновано також методи, які необхідно реалізувати, щоб зробити агропромисловий комплекс конкурентоспроможним на світовому ринку. Результати цього дослідження конкурентоспроможності українських агрохолдингів на міжнародних ринках та зроблені на їх основі висновки мають важливе значення, оскільки доводять, що в Україні діють потужні агрохолдинги, які характеризуються динамічними можливостями, нарощують свої потужності, залучають невикористані орні землі, та ефективно використовують потенціал ресурсів і посівів. Крім того, перспективним для агрохолдингів є освоєння світових ринків сільськогосподарської продукції, адже Україна географічно розташована майже в центрі міжнародних торговельних мереж, а експорт за окремими стратегічними напрямками допоможе аграрним підприємствам уникнути невизначеності та можливих великих збитків. Оцінка агрохолдингів, а саме «Кернел» і «Миронівський хлібпродукт», показала, що навіть в умовах війни агрокомпанії мають можливості для розвитку та виходу на міжнародні ринки. Отримані в рамках дослідження результати можуть бути використані як представниками громадського сектору для формування політики у цій сфері, так і підприємствами для створення довгострокових стратегій розвитку

► **Ключові слова:** сільське господарство; конкуренція; виробництво; ринки збуту; експорт

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