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AGRICULTURAL ENGINEERING: STAGNATION OR BIOECONOMIC ONTOGENESIS

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СІЛЬСЬКОГОСПОДАРСЬКЕ МАШИНОБУДУВАННЯ: СТАГНАЦІЯ ЧИ БІОЕКОНОМІЧНИЙ ОНТОГЕНЕЗ

The article is devoted to the analysis of the current state of agricultural engineering in Ukraine, which is in stagnation, but has the potential for transformation through a bioeconomic approach. The study considers the possibilities of overcoming crisis phenomena in the industry through innovation, digitalization and adaptation to global environmental and economic challenges.

The purpose of the article is to analyze the current state of agricultural engineering in Ukraine, identify the causes of stagnation and justify the strategies of its bioeconomic ontogenesis, which provides for the evolutionary development of the industry based on the principles of sustainability, innovation and integration into global value chains. The study used data from the State Statistics Service of Ukraine, analytical reports of the KSE Institute, the Ministry of Agrarian Policy and Food. Methods of comparative analysis, statistical data processing, systematization and generalization were applied to assess the dynamics of production, import, export and structural changes in the industry for the period 2017—2024. The study found that the industry suffered significant losses due to military operations, in particular the destruction of 182 thousand units of equipment, which accounts for 56.7% of the losses in the agricultural sector. In 2022, there was a sharp reduction in production and imports, especially tractors (by 74.4% in the 37—75 kW segment) and sowing equipment (by 38.4%). At the same time, individual enterprises demonstrated resilience by increasing the production of irrigation equipment. Signs of a transition to a bioeconomic model were identified, which is manifested in the growth of

the production of energy-saving equipment and adaptation to climate challenges. Post-war activation measures were proposed, including modernization, the creation of R&D centers and personnel training. Further research should focus on developing models of cluster interaction in the industry, assessing the effectiveness of state support and analyzing the impact of integration with the EU on technological localization. It is important to explore the potential of digital technologies and artificial intelligence in agricultural machinery to ensure competitiveness in the global market.

Стаття присвячена аналізу сучасного стану сільськогосподарського машинобудування України, яке перебуває в умовах стагнації, але має потенціал для трансформації через біоекономічний підхід. Дослідження розглядає можливості подолання кризових явищ у галузі шляхом інновацій, цифровізації та адаптації до глобальних екологічних і економічних викликів.

Метою статті є аналіз сучасного стану сільськогосподарського машинобудування України, виявлення причин стагнації та обґрунтування стратегій його біоекономічного онтогенезу, що передбачає еволюційний розвиток галузі на основі принципів сталості, інновацій та інтеграції в глобальні ланцюги вартості. У дослідженні використано дані Державної служби статистики України, аналітичні звіти KSE Institute, Міністерства аграрної політики та продовольства. Застосовано методи порівняльного аналізу, статистичної обробки даних, систематизації та узагальнення для оцінки динаміки виробництва, імпорту, експорту та структурних змін у галузі за період 2017–2024 років. Дослідження виявило, що галузь зазнала значних втрат через воєнні дії, зокрема знищення 182 тис. одиниць техніки, що становить 56,7% збитків аграрного сектору. У 2022 році спостерігалось різке скорочення виробництва та імпорту, особливо тракторів (на 74,4% у сегменті 37–75 кВт) і посівної техніки (на 38,4%). Водночас окремі підприємства, продемонстрували стійкість, нарощуючи випуск іригаційної техніки. Виявлено ознаки переходу до біоекономічної моделі, що проявляється у зростанні виробництва енергоощадної техніки та адаптації до кліматичних викликів. Запропоновано заходи післявоєнної активізації, включаючи модернізацію, створення R&D центрів і кадрову підготовку. Подальші дослідження мають зосередитися на розробці моделей кластерної взаємодії в галузі, оцінці ефективності державної підтримки та аналізі впливу інтеграції з ЄС на технологічну локалізацію. Важливим є вивчення потенціалу цифрових технологій і штучного інтелекту в сільськогосподарському машинобудуванні для забезпечення конкурентоспроможності на глобальному ринку.

Key words: agricultural machinery, war, import dependence, technical losses, bioeconomy, state regulation.

Ключові слова: сільськогосподарське машинобудування, війна, імпортозалежність, технічні втрати, біоекономіка, державне регулювання.

GENERAL STATEMENT OF THE PROBLEM AND ITS CONNECTION WITH IMPORTANT SCIENTIFIC OR PRACTICAL TASKS

The relevance of the study is due to the critical role of agricultural engineering in Ukraine's economy, which has historically been one of the key industries but is currently stagnating. In the context of global challenges such as climate change, rising food demand, and the transition to a bioeconomy, the industry has the potential to transform through innovation, digital technologies, and environmentally friendly approaches. However, the current state of Ukrainian agricultural machinery is characterized by low competitiveness, dependence on machinery imports, insufficient funding, and limited innovation activity, which hinders its development in the international market. The study of this topic is important for identifying ways to overcome the crisis, in particular by analyzing the possibilities of bioeconomic ontogeny — the evolutionary development of the industry based on the principles of sustainability, the use of bioresources and

the introduction of resource-saving technologies. The relevance is also reinforced by the need to adapt to European standards. Thus, the article is aimed at substantiating strategies for reviving the industry, which will contribute to economic growth, food security and sustainable development of Ukraine.

ANALYSIS OF THE LATEST RESEARCH AND PUBLICATIONS

In their studies, Holovnia O., Chemeris Y. [3] analyze in detail the key prerequisites for the formation of the machine-building industry in Ukraine, in particular, focusing on the impact of institutional changes, the specifics of the territorial location of enterprises and the peculiarities of intersectoral cooperation, which necessitates an integrated approach to assessing its dynamics.

Ishchuk O. [9] systematizes the stages of development of the industry, highlighting the periodization of its functioning in the context of changes in the political and economic environment, which allows to outline the boundaries between

the phases of growth, stagnation and adaptive recovery. In turn, A. Tselikova and E. Misko [1] emphasize the importance of the innovation factor, considering the modernization of machine-building production as a prerequisite for ensuring its competitiveness in the context of globalized markets and technological breakthroughs [3].

The works of Bilovod O. I., Popov S. V. [2], Spomer T., Voloshyn S., Reus R. [13] substantiate the need for an in-depth study of individual subsectors of mechanical engineering, among which agricultural engineering is distinguished as strategically important for the national economy due to its direct impact on the efficiency of agricultural production, ensuring mechanized land cultivation and the formation of technical independence of the agricultural sector. The analysis proposed by Makedon V., Kholod O., Yarmolenko L. [6] is also worthy of attention, in which special emphasis is placed on the importance of the cluster approach, which allows to consider the machine-building industry as a system of interconnected enterprises united by a common innovation, production and logistics infrastructure. Despite the existence of thorough studies, most of them do not fully cover the specifics of the functioning of agricultural machinery as a separate industry segment, which requires a detailed study of its structure, dynamics, export-import balance, and level of technological localization.

FORMULATION OF THE OBJECTIVES OF THE ARTICLE (TASK STATEMENT)

The purpose of the article is to provide a comprehensive justification for the strategy of restoration and modernization of agricultural machinery in Ukraine under martial law, as well as to analyze the possibility of transition to a bioeconomic model as a factor of sustainable development.

Objectives of the study:

- to study the dynamics, structure and current trends of the industry during the war and post-war periods, taking into account the export-import balance, segmentation by type of equipment and participation of enterprises of various sizes;
- to assess the scale of losses from the full-scale aggression of the Russian Federation and identify critical infrastructure nodes that need to be resto-

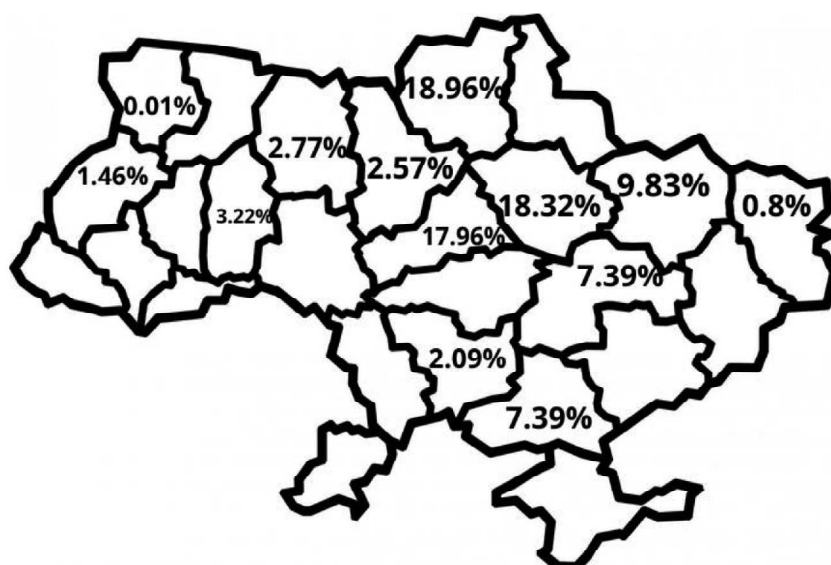


Fig. 1. Share of regional manufacturers in total sales of agricultural machinery, as of the beginning of 2022

Source: based on [9].

red, modernized or reindustrialized in accordance with the principles of sustainable and bio-based development;

- to substantiate the directions of state policy and develop institutional and economic measures to enhance innovation, support local production and reduce import dependence.

SUMMARY OF THE MAIN RESEARCH MATERIAL

In the context of the ongoing transformations caused by both military actions and global economic fluctuations, the development of the agricultural machinery market in Ukraine in 2024 shows clear signs of a change in the structure of supply and demand, indicating a shift from the classic model of updating the technical fleet through the import of new machines to an adaptation model based on the reuse of existing resources. According to analytical forecasts, this year the downward trend in agricultural machinery imports will continue, although the dynamics of this process is gradually slowing down, which gives grounds to speak not so much of a slowdown in the decline as of a gradual formation of a new equilibrium in the system of technical support for the agricultural sector (Fig. 1).

According to the official information published by the State Statistics Service of Ukraine, the vast majority of legal entities registered under CEA 28.3 "Manufacture of machinery and equipment for agriculture and forestry" are classified as small and micro enterprises, and more than 67% of them have up to 9 employees, which indicates the fragmented and extremely small nature of the

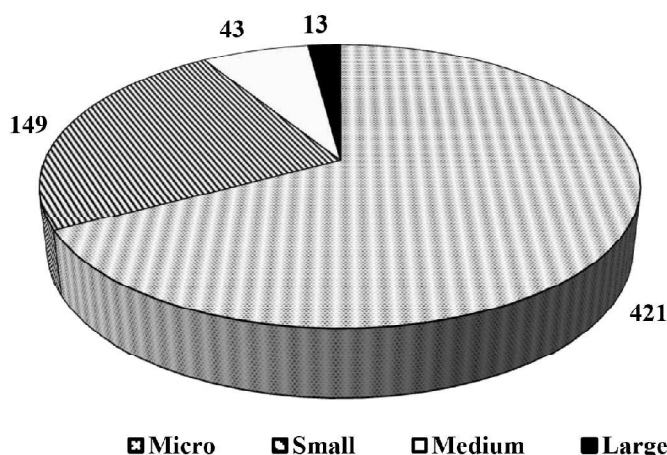


Fig. 2. Distribution of registered companies operating in the field of agricultural machinery by the number of employees (as of the beginning of 2022)

Source: based on [8].

production base in this industry. The agricultural machinery market is segmented into the following product groups [5]:

1. Elevator equipment.
2. Attachments; harrows, cultivators, cultivators, threshers and attachments, plows, seeders, planters and seedling planters, fertilizer spreaders and distributors
3. Tractors: up to 100 hp, from 100 hp.
4. Harvesting machinery; grain harvesting (combines), mowers, root crop harvesting.

This structure significantly complicates not only ensuring stable production growth, but also the implementation of large investment projects

Table 1. Production of agricultural machinery in Ukraine by manufacturers (2020–2024), units per year

Manufacturer	Type of equipment	Years				
		2020	2021	2022	2023	2024
KhTZ (Kharkiv Tractor Plant)	Tractors	600	550	300	350	400
Lozova machines	Attachments, seeders	700	750	500	550	600
Kobzareno plant	Trailers, bins, elevator equipment	800	850	600	650	700
Elworthy (Red Star)	Seeders, cultivators	500	520	400	450	480
Berdiansk reapers	Harvesters, reapers	300	280	0	0	0
Fregat plant	Irrigation equipment	250	270	280	290	310
Boguslavsk Agricultural Machinery Plant	Sprayers, cultivators	400	420	350	370	390
Agro-Soyuz	Seeders, tillage equipment	450	470	380	400	420

Source: based on [1].

related to the introduction of innovative technologies and automation (Fig. 2).

Over the past five years, the agricultural machinery industry in Ukraine has undergone significant structural changes, which have manifested themselves in fluctuations in machinery production volumes, transformation of the production potential of leading machine-building enterprises, changes in priorities in the product portfolio, and responses to the challenges of external geopolitical and climate turbulence. The dynamics recorded in the table, which reflects the production of machinery by key domestic manufacturers in 2020–2024, allows us to consider the current state of agricultural machinery through the prism of two mutually exclusive trends of stagnation as a result of objective constraints and crises, as well as bioeconomic ontogeny as a process of evolution, renewal and adaptation of the industry to the needs of modern agriculture (Table 1).

First, the analysis of the table clearly demonstrates the presence of a pronounced crisis period in 2022, when most manufacturers, including such systemic players as Kharkiv Tractor Plant, Elworthy (formerly Chervona Zvezda), and Lozovskie Machines, significantly reduced their machinery output, which was caused not only by the military actions occupation of certain territories, logistical constraints and destruction of production infrastructure, but also due to the overall decline in domestic demand for machinery from farmers who faced a lack of financing, reduced profitable activities and limited investment in long-term assets (Table 2). 2).

Secondly, in addition to signs of recession, there are markers of a slow but consistent transition to a new paradigm, characterized by a shift in emphasis to the production of machines that meet the principles of sustainable agriculture, the economical use of natural resources, and integration into the bioeconomy. In this context, the growth in the production of irrigation equipment by the Fregat plant in the most difficult year (2022) is particularly indicative, which shows the transition of the agricultural sector to a more adaptive management format focused on combating the effects of climate change, soil erosion, and water shortages [6].

We also pay attention to the diversification strategies implemented by enterprises, for example, Kob-

Table 2. Origin of capital of TOP-10 Ukrainian companies (determined by production in monetary terms in 2022)

Company.	Capital
Kobzareno plant	Ukrainian (previously with a German share)
PJSC "Boguslavska Silhospstekhnika"	Ukrainian
PE "LubnyMash"	Ukrainian
Elworthy JSC	Ukrainian
PJSC "Karlivka Machine-Building Plant"	Ukrainian
LLC "Warehouse modernization systems"	Ukrainian
LLC "Variant Agro Bud"	Ukrainian
LLC SPE "Bilotserkivmaz"	Foreign (Cyprus)
Duvelsdorf Ukraine LLC	Foreign (Germany)
PJSC "VOSKHOD"	Ukrainian

Source: based on [7].

zarenko Plant has consistently increased the production of elevator equipment, trailers, and bins, which reflects the change in logistics chains and the need to increase the self-sufficiency of agricultural enterprises in technical means after the reduction in the availability of imports. In this aspect, we can see the desire of Ukrainian producers to transform their development models, with a transition from mass production of universal units of equipment to the creation of technological solutions that help reduce the burden on the environment, energy saving and increase the efficiency of bioresources use.

An analysis of the dynamics of the agricultural machinery market in Ukraine, taking into account the market capacity in monetary terms, shows a cyclical nature of development, which is significantly correlated with both external economic conditions and domestic political and security factors. In particular, after the easing of restrictions related to the COVID-19 pandemic, the market responded with a rapid increase in imports, which confirms the existence of pent-up demand and high dependence on external supplies of technical equipment [9]. At the same time, the decline in total market capacity in 2022 was a direct consequence of the full-scale war, but it also reflects a return to medium-term trends characteristic of the pre-crisis period (Table 3).

It is worth emphasizing that 2021 was a period of intensive growth in all major product groups of agricultural machinery,

with the most dynamic growth recorded in the irrigation equipment segment, indicating the adaptive response of the agricultural sector to the challenges of climate change. Instead, in 2022, most product groups experienced a decline, with the exception of the tractors and elevator equipment segments, where volumes remained at the level of the previous year, due to the need to urgently replace lost equipment, as well as the impact of devaluation processes that led to a significant increase in unit prices (Table 4) [15].

As of 2023, the production of tractors and harvesting equipment in Ukraine is characterized by critically low indicators, while the production of irrigation and elevator equipment demonstrates relative stability and competitiveness. Given that market assessments are made in monetary terms, it is important to take into account that imported machinery is usually significantly more expensive than domestic counterparts, which artificially shifts the emphasis towards import dominance. Tractors and harvesting equipment remain the most import-dependent, while in the segments of attachments and elevator equipment Ukraine has its own high-quality production that offers cost-effective alternatives. The data that allows us to classify equipment by the criterion of novelty is limited to 2022 inclusive, which makes it difficult to assess the structure of imports after the start of a full-scale war. At the same time, in 2022, the largest share of used machinery in imports was tractors (15.6%), harvesting equipment (14.4%), irrigation equipment (7.0%), elevator equipment (2.4%), and attachments (2.3%), which indicates the heterogeneity of the technical fleet in terms of wear and tear.

Within the shadow market, three main segments can be distinguished: first, the so-called gray imports, when the cost of equipment is deliberately understated or imported under codes with lower duties; second, the purchase of spare parts, in particular for precision farming equipment,

Table 3. Capacity of the agricultural machinery market, 2017–2022, in monetary terms, mln. USD

Indicator.	2017	2018	2019	2020	2021	2022
Production	414,85	375,82	240,10	128,03	157,03	106,13
Imports	3154,95	2738,83	2401,91	2134,30	3309,00	2614,32
Exports	132,24	120,49	116,01	101,59	140,54	92,58
Market capacity	3437,56	2994,16	2525,99	2160,74	3325,49	2627,87
Growth, %, year on year	—	-13	-16	-14	54	-21

Source: based on [15].

Table 4. Agricultural machinery market capacity, 2017–2022, in monetary terms, USD million US segmented by product group

Category.	Indicator.	2017	2018	2019	2020	2021	2022
Irrigation equipment	Production	13,06	16,84	14,08	11,19	20,57	21,03
	Imports	85,3	93,76	68,57	85,93	102,61	63,56
	Exports	6,44	9,17	9,16	10,65	45,36	6,67
	Market capacity	91,92	101,43	73,49	86,47	77,82	77,79
	Growth, %, year on year	11%	11%	-27%	18%	-24%	-40%
Elevator equipment	Production	30,01	28,23	29,18	25,74	24,63	23,27
	Imports	73,86	66,6	75,7	44,06	54,31	50,65
	Exports	75,26	58,66	59,75	40,62	32,63	46,05
	Market capacity	28,61	36,18	45,13	29,18	46,31	27,87
	Growth, %, year on year	-7%	26%	25%	-35%	59%	-40%
Mounted equipment	Production	247,42	264,06	186,45	35,82	61,16	51,75
	Imports	642,79	599,49	590,33	674,13	713,42	613,85
	Exports	62,68	54,92	59,19	63,66	66,79	61,38
	Market capacity	827,53	808,63	717,59	646,29	707,79	604,22
	Growth, %, year on year	-30%	-2%	-11%	-10%	10%	-15%
Harvesting equipment	Production	56,22	47,34	32,54	40,33	41,75	43,62
	Imports	961,04	663,51	510,04	524,78	485,34	554,43
	Exports	21,84	17,02	14,33	27,94	34,53	43,53
	Market capacity	995,53	693,83	528,25	537,87	492,56	554,43
	Growth, %, year on year	-17%	-30%	-24%	2%	-8%	13%
Tractors	Production	68,16	123,15	100,52	43,53	60,32	32,28
	Imports	1386,29	1279,76	1222,68	1063,99	1539,89	1603,02
	Exports	6,22	74,63	72,83	34,13	35,81	70,66
	Market capacity	1448,72	1328,24	1250,53	1072,79	1564,43	1564,63
	Growth, %, year on year	-8%	-8%	-6%	-14%	46%	-6%

Source: based on [16; 17].

bypassing official channels; and third, cottage industry, which includes the manufacture of simple attachments for low-powered tractors, which is common in small farms. According to expert estimates, the share of artisanal production can reach 15–20%, while the volume of illegal supplies in the form of gray schemes and spare parts generally does not exceed 5% of the market (Table 5) [1].

Regarding tractors, the only product group for which a capacity split is maintained, it is important

to note that due to the lack of large-scale domestic production, the relevant estimate is based solely on imports. Thus, according to 2021 data, the structure of imports in monetary terms is fairly uniform: 48% are tractors with a capacity of up to 100 hp, and 52% are more powerful models, which demonstrates a balanced demand among different categories of agricultural producers.

In the context of limited access to foreign machinery, which is the result of both broken logistics and the financial inaccessibility of expensive equipment, there is an increasing trend towards the growth of used machinery imported or sold in the domestic market through exchange, restoration and modernization mechanisms. This process is accompanied by an increased demand for spare parts, expansion of repair services, and the emergence of new market participants, such as companies such as Bas-Agro Group LLC, which produce components on their own in Ukraine, in particular in the city of Cherkasy, thereby contributing to import substitution and preserving the technical potential of farms [7].

Data provided by the press service of the National Research Center "Institute of Agrarian Economics" confirm that in 2023 there was a

significant decrease in the volume of agricultural machinery imports to Ukraine, which was especially evident in such critical segments as tractors, combine harvesters, and sowing equipment. Thus, according to Yaroslav Navrotsky, a leading researcher at the Institute, the most rapid decline was recorded in the category of tractors with an engine power of 37–75 kW — from 5566 units in 2021 to 1969 units in 2022, and then to only 503 units in 2023, which indicates a 74.4%

Table 5. The share of agricultural machinery imports in 2022, in monetary terms, mln. USD million with segmentation by product groups

Product group	Imports, mln. U.S. DOLLARS	Production, mln. U.S. DOLLARS	Share, %.
Tractors	1585,2	32,2	98%
Harvesting equipment	560,5	2,9	99%
Attachments for harvesting	379,4	26,6	93%
Elevator equipment	45,7	23,3	66%
Irrigation equipment	43,5	21,0	67%

Source: based on [18].

decrease in imports. The decline in imports of medium-power tractors (75-130 kW) was also noticeable, from 1865 to 1453 units between 2022 and 2023, a 22.1% decline. Even the segment of the most powerful tractors with an engine over 130 kW, which has traditionally remained relatively stable, recorded a decrease of 6.3% from 1253 to 1174 units over the same period [4].

As for other key types of machinery, including combine harvesters, imports in 2023 decreased by 9.4% (from 2104 to 1906 units), while the volume of sowing machinery decreased by 38.4% from 4465 to 2749 units. A particularly sharp decline was observed in the plow category: after a significant increase in 2022, when imports reached 2779 units, in 2023 the volume almost halved to 1332 units. At the same time, imports of disk harrows and mowers remained relatively stable with a slight negative trend [4].

Given that a number of domestic agricultural machinery enterprises have been completely or partially destroyed as a result of hostilities, are under temporary occupation, or have lost access to strategic resources, the opportunities for renewing the national agricultural sector's machine and tractor fleet have significantly narrowed. This situation leads to the forced continuation of the operation of outdated, technically worn-out equipment, which in turn leads to higher maintenance and repair costs, increased energy intensity of production processes and, as a result, an increase in the cost of agricultural products while reducing

labor productivity. In his comments, Yaroslav Navrotskyi noted that the continuation of the current trend could lead to a significant shortfall in harvest, as the lack of modern equipment makes it impossible to effectively perform agricultural work in critical agrotechnical terms [19, p. 52].

It is worth noting that the domestic market of agricultural machinery in Ukraine is represented by both domestic manufacturers of machinery and a wide segment of imported equipment, a significant share of which comes from the European Union, the United States and other technologically advanced countries. Imported products, on the one hand, help to increase competition and accelerate the modernization of the technical park of agricultural producers, and on the other hand, strongly displace local enterprises that are unable to fully compete in an open market without government support. In 2020, there was a noticeable decline in imports of attachments due to quarantine restrictions and global logistics disruptions caused by the COVID-19 pandemic, but the market resumed growth in the following period after the restrictions were eased.

It is significant that in 2022, the agricultural machinery market suffered a deep crisis caused by the outbreak of full-scale military aggression by the Russian Federation, which resulted in both direct losses of machine-building enterprises' capacities due to destruction or occupation and indirect factors: blocking of logistics routes, fuel shortages, export restrictions and a critical decline in demand for new machinery due to uncertainty in the agricultural market. Particularly noteworthy is the production of tractor mowers, which showed the deepest decline during the study period, due to the loss of one of the key manufacturers located in the temporarily occupied city of Berdiansk [10]. These things indicate not only

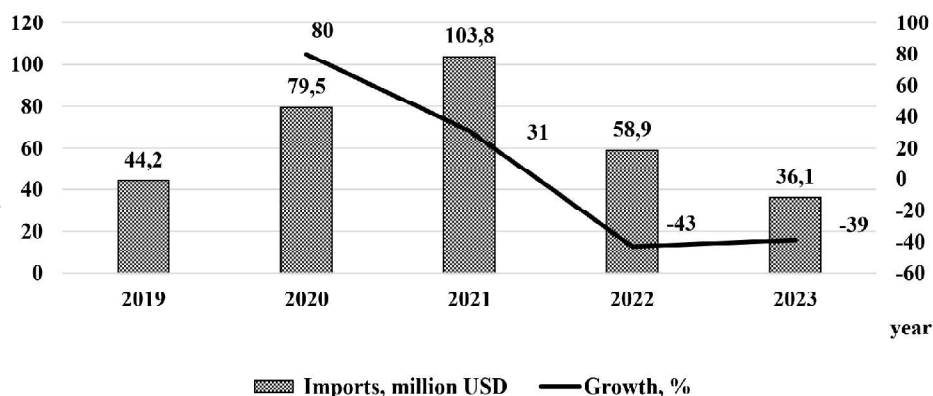


Fig. 3. Dynamics of imports of attachments to Ukraine in 2019–2023 (pcs.)

Source: based on [16].

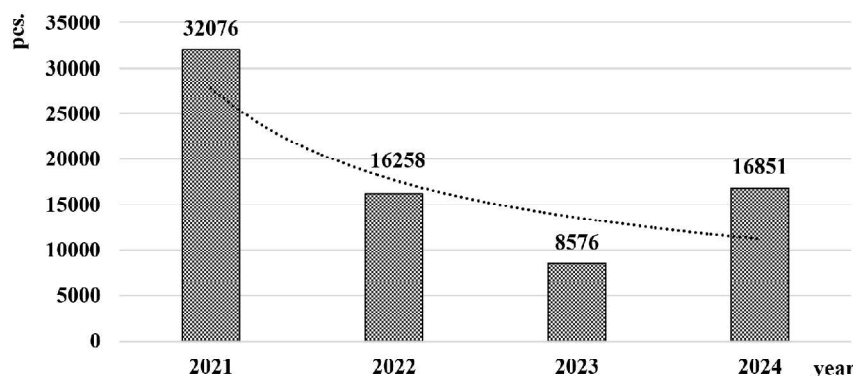


Fig. 4. Dynamics of tractor imports to Ukraine in 2021–2024 (pcs.)

Source: based on [16].

losses for a specific product segment, but also structural threats to the integrity of the agricultural machinery industry as a whole (Fig. 3).

In addition, it is worth noting that the curtailment of exports of domestic machinery in 2022 was due not only to the objective circumstances of martial law, but also to the strategic reorientation of the machine-building potential to the domestic market, which faced a shortage of machinery due to the suspension of supplies from abroad. Disruptions in logistics chains, changes in the cost structure of agricultural producers, and a decline in export activity have led to Ukraine losing some of its positions in the Central European markets, where it used to actively export attachments, sprayers, and seeders [2].

The tractor industry, as one of the key elements of Ukraine's agricultural machinery, was already in a state of unstable development before the full-scale military invasion, which was manifested in a low level of technological modernization, limited investment attractiveness, and significant dependence on imported machinery. With the beginning of the active phase of hostilities, the crisis in this industry has further aggravated, due to both direct destruction of production infrastructure and loss of access to the regions where the leading enterprises of the industry were located. In particular, one of the key enterprises, Berdiansk Harvesters PJSC, which specialized in the manufacture of reapers and mowers, found itself in the occupation zone, which effectively led to the suspension of its production activities for an indefinite period. At the same time, the Kharkiv Tractor Plant, which is the flagship of the industry, was damaged by shelling, and part of its production facilities, according to unconfirmed information, was reoriented to service other equipment, which makes open analytics difficult due to security concerns (Figure 4).

In this context, it becomes obvious that further development of the domestic tractor industry as a sub-sector of agricultural machinery directly depends on the intensification of international technical and investment cooperation, in particular in terms of the introduction of advanced engineering solutions, digital control systems for agricultural machinery, localization of new generation units and assemblies that meet the requirements of sustainable development [13, p. 231].

At the same time, it cannot be ignored that the recovery of production in 2023–2024 is limited: the recovery in volumes only partially compensates for the losses of previous years, and without targeted modernization, including investment in research and engineering education, the risk of a stagnant scenario persists. The disappearance of Berdiansk Harvesters from the production map looks particularly critical, making it impossible to resume production of complex machines in the short term.

An analysis of the current state of agricultural machinery in Ukraine shows that this industry has suffered significant structural and economic losses as a result of the full-scale military invasion of the Russian Federation, which, in turn, has significantly worsened its production potential and technological capability. Based on the estimates prepared by the KSE Institute in cooperation with the Ministry of Agrarian Policy and Food of Ukraine, it was found that the total losses incurred by the aggression in the agricultural sector of the country amounted to USD 10.3 billion. The most vulnerable component of this damage was the agricultural machinery sector, which accounted for more than 56.7% of total losses, indicating the critical vulnerability of the mechanized resource of Ukrainian farmers to military threats (Fig. 5).

It is worth emphasizing that as a result of the hostilities, more than 182 thousand units of agricultural machinery and equipment were partially or completely destroyed, which confirms the depth of the systemic crisis in the sector of technical support for agricultural production. In view of the above, it becomes obvious that there is a need for a comprehensive rethinking of the functioning of agricultural engineering in Ukraine as a separate strategic industry that has a direct impact on food security, technical independence of agriculture and restoration of the potential of the post-war economy [19; 20, p. 125].

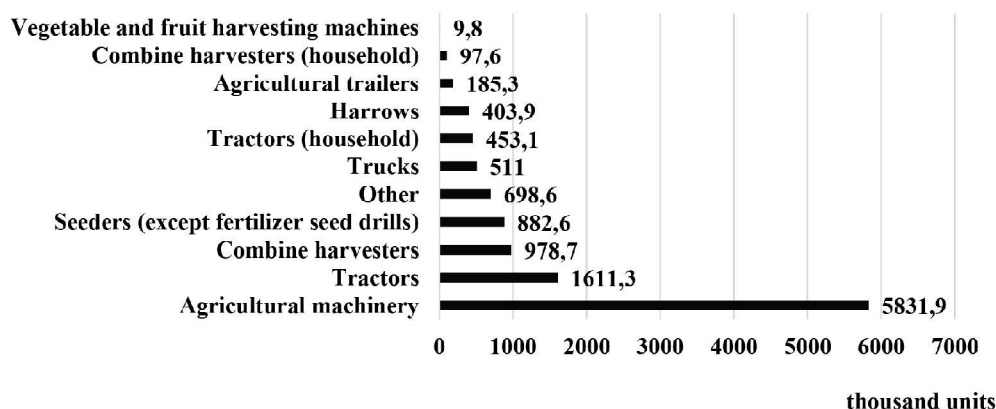


Fig. 5. Losses of different types of agricultural machinery at the end of 2024

Source: based on [1].

In this context, the issue of forming an effective regulatory framework that would provide conditions for stabilizing the situation in the industry and facilitate its transition from stagnation to a phase of institutional renewal within the bioeconomic paradigm becomes particularly relevant. Today, the functioning of agricultural engineering in Ukraine is regulated by a number of legislative acts, resolutions of the Cabinet of Ministers of Ukraine, regulations of the Ministry of Agrarian Policy and Food, the Ministry of Industrial Policy, as well as other regulatory documents aimed at supporting industrial production in the agrarian and technical sector [11, p. 526; 21].

Among the key regulatory documents is the Law of Ukraine "On Stimulating the Development of Domestic Machinery for the Agro-Industrial Complex" of 07.02.2002 No. 3023-III (as amended on 16.10.2020), which establishes approaches to supporting the national producer by creating tax, financial and technical incentives. The Law of Ukraine "On the System of Engineering and Technical Support of the Agro-Industrial Complex of Ukraine" of 05.10.2006 No. 229-V (as amended on 31.03.2023) establishes the principles of organizational interaction between manufacturers, suppliers and consumers of machinery. At the same time, the Law of Ukraine "On Protection of the Rights of Buyers of Agricultural Machinery" No. 900-IV guarantees consumers proper product quality and protection mechanisms in case of violation of the terms of operation and service [3; 22].

In addition, the legal infrastructure for supporting the industry is complemented by the provisions of the Law of Ukraine "On the Priority of Social Development of Rural Areas and the Agro-Industrial Complex in the National Economy" of October 17, 1990, as well as the Law of Ukraine "On State Support of Agriculture of Ukraine" of June 24, 2004 (revised on November 04, 2018), which create the

Table 6. Measures of post-war revitalization of agricultural machinery in Ukraine

№	Strategic direction	Main events	Expected results	Deadline for completion	Those responsible
1	Modernization of production	Introduction of automated lines and digital technologies	Increase in productivity by 30%	2025–2027	Ministry of Economy, industry enterprises
2	Innovative activity	Establishment of R&D centers for the development of bioeconomic equipment	Release of 5 new models of equipment	2026–2028	Scientific institutes, private sector
3	Financial support	Provision of preferential loans and government grants	Attracting \$500 million in investments	2025–2029	Government, international donors
4	Export strategy	Participation in international exhibitions, conclusion of trade agreements	Increase in exports by 25%	2026–2030	Ministry of Economy, chambers of commerce
5	Environmental transformation	Development of machinery for organic farming	Reduction of CO ₂ emissions by 20%	2027–2030	Enterprises, environmental organizations
6	Personnel training	Launch of training programs for engineers and technologists	Training of 10,000 specialists	2025–2030	Ministry of Education and Science, specialized universities

Source: compiled by the author.

preconditions for an integrated policy in the field of technical and technological renewal of agriculture [11].

The Law of Ukraine "On Amendments to Certain Laws of Ukraine on the Exercise of Technical Regulation Functions in the Field of Agricultural Sector and Machinery for the Agricultural Sector" of 31.05.2022 deserves special attention in the context of adaptation of Ukrainian legislation to EU requirements [23]. This document aims to harmonize the regulatory framework with European standards, strengthen control over the quality of machinery, improve certification procedures and create an institutional framework for transparent and fair regulation of activities in the sector.

Government policy, including programs to compensate for the cost of domestic machinery, the development of industrial parks, and the creation of conditions for the integration of Ukrainian enterprises into global value chains through cooperation with foreign partners and localization of production of modern machine models, is also a promising factor in restoring the machine-building potential.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH IN THIS AREA

The study found that Ukraine's agricultural machinery industry is one of the most vulnerable industries during martial law. This sector has suffered the most, both in terms of physical volume of destroyed equipment and in monetary terms, where the share of losses exceeds 56% of the total losses of the agricultural sector. An analysis of the domestic machinery market by segment (tractors, harvesting, irrigation, attachments, and elevator equipment) revealed significant import dependence, especially in the production of tractors (98%) and harvesting equipment (99%). The study of the dynamics of agricultural machinery production in 2020—2024 showed a crisis turning point in 2022, which became critical for most producers due to military operations, infrastructure destruction, loss of sales markets, and reduced solvency of farmers. At the same time, there is a trend toward bioeconomic ontogeny, which is manifested in the attempts of enterprises to reorient themselves to the production of energy-efficient and environmentally responsible machinery capable of operating in the face of resource constraints and climate risks.

The recovery and transformation of the industry is possible only if a systemic state policy

is implemented, which provides for the modernization of production, financial support for enterprises, stimulation of innovation, and adaptation of the regulatory framework to EU standards. The developed strategic matrix for the post-war recovery of agricultural machinery includes institutional, financial, human resources, export, technological and environmental measures with clearly defined expected results and deadlines.

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