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## Production as a link in the market of agricultural machinery for crop farming in Ukraine

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► **Abstract.** The production of agricultural machinery and equipment in Ukraine is one of the main sources of supplying the market with resources and facilities for agricultural production, but as of 2023, it does not fully meet its needs. According to the relevance of the subject matter, the purpose of the study was to investigate the trends in the development of the agricultural engineering industry in Ukraine in dynamics, the impact of military operations on it, and to work out effective ways to overcome their negative consequences. The following methods were used: dialectical, statistical and economic, graphical, index, correlation and regression analysis, empirical, comparative analysis, analytical forecasting, abstract logical, etc. The principles of regional placement of agricultural engineering enterprises are defined, depending on the availability of raw materials, energy and labour resources. The structure of enterprises in the industry by category is determined – most of them are small enterprises (85.8-91.5%), but the majority are employed by medium-sized enterprises (59.1-79.3%). Due to military operations, the number of active enterprises in the industry has decreased by about 30 units. The trend of reducing the production of tractors, combine harvesters, and some types of tillage machines in Ukraine and the reasons for its occurrence are revealed. The prospects of production of sowing equipment in Ukraine are substantiated. The index of identified comparative advantages of different countries by individual types of machinery is analysed, and it is found that in Ukraine only tillage machinery has a high level of advantages – 1.802 and has optimistic prospects for development. The paper defines a close correlation between the export and production of tractors in Ukraine in 2010-2021 (the corresponding correlation coefficient – 0.8982). Problems that hinder the development of the agricultural machinery industry are identified: inflation, disruption of logistics links and loss of suppliers, high prices for energy resources, etc. Recommendations for overcoming them are proposed: creating favourable investment conditions; implementing protectionist customs and tax policies for industry enterprises; evacuating them from the war zone. The proposed measures will contribute to the restoration, preservation, and progressive innovative development of the potential of agricultural engineering in Ukraine

► **Keywords:** agricultural engineering; export; profit; placement of enterprises; import; tillage equipment

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## ► Introduction

The determining factors for the development and effective functioning of any commodity market, including the market of agricultural machinery and equipment, is the balance of supply (formed primarily by domestic production and imports) and demand (formed by consumers of the corresponding products). Ukraine's own production of agricultural machinery is not only a prerequisite for the effective development of the domestic agricultural sector, but also a factor in preserving and improving the quality of labour potential, ensuring stable budget revenues, preventing the outflow of foreign currency from the country, and stimulating its inflow through increased exports, development of logistics and social infrastructure, etc.

H. Bernhardt *et al.* (2021) focused on the interaction between Industry 4.0 and Agriculture 4.0. The researchers suggest that network interaction between producers of mechanisation tools is necessary to maximise the satisfaction of agricultural needs in innovative technology, which contributes to the use of a set of innovative products of Industry 4.0 directly for agriculture. R. Vidosa *et al.* (2022) substantiated the need for the transition of agricultural machinery to ISO 11783 (ISOBUS) standards at the global level to achieve compliance of machinery with the requirements of Agriculture 4.0 and the retention of the market segment at the local level, competing with multinational companies. Compliance with these standards will also contribute to the development of effective business models related to the maintenance of machinery and equipment.

The risk assessment for autonomous agricultural machines was investigated by J.M. Shutske *et al.* (2023). According to the researchers, the safety of agricultural machinery is a problem for stakeholders and an obstacle to the widespread introduction of automated technical means. Based on the survey of engineers-practitioners and researchers who design automated and autonomous agricultural machines, the needs beyond interference and operator injury prevention were identified: safety issues and risks associated with farm animals, property, infrastructure, downtime, and the environment. The researchers proposed ways to further develop safety standards, including the need for software and operational data for designing autonomous machines.

Z.-L. Zhao *et al.* (2022) suggest that data on warranty cases for assessing the reliability of equipment in the field by its manufacturers is the most easily accessible and valuable source of information. Identifying the relationship between product reliability and reliability factors is one of the key factors for improving product quality. The researchers used the random survival forest (RSF) method, which is adapted for machine processing and analysis, to model the reliability level. The quality of tractors was investigated by Y. Li *et al.* (2019), who substantiated the crucial importance of the supply chain in the manufacturing process, since most of the components come from external suppliers. The proposed approach allows evaluating the supplier based on the analysis of data from incoming quality control and maintenance of equipment after its sale.

B. Sui *et al.* (2019) analysed scientific and technical innovations in agricultural engineering in three aspects: industrial development, environmental revival, and human

resources revival. The researchers suggest that the key task of scientific and technical innovations in agricultural engineering is precisely the training of personnel in the future. To increase the competitiveness of Ukrainian-made equipment, G.O. Kovalenko & O.G. Kovalenko (2021) offer: to update production equipment at enterprises; to implement the transition to international standards of production of equipment; to introduce strict control over product quality; to establish cooperation with research institutions on mutually beneficial terms.

The purpose of the study by A. Hoose & M. Kripka (2021) was an assessment of the environmental impact of technologies in agricultural engineering throughout the process chain. The study analysed the production process of a product and assessed its impact on the environment based on three factors of damage caused: human health, ecosystem, and resource scarcity. A close correlation was found between the use of carbon and stainless steel, the laser processing process, and the environmental impact. In this case, the factor of harm to human health lies in an increase of the greenhouse effect. The use of natural resources for energy needs is the most influential factor in creating a shortage of minerals.

A. Malik & S. Kohli (2020) identified the advantages of the production and operation of electric agricultural machinery and the problems associated with its introduction into agricultural production. The researchers considered high torque, low operating and maintenance costs, and no harmful emissions to be the advantages. Deterrent factors were: high initial cost, lack of charging infrastructure and insufficient perception of the harmfulness of equipment emissions on conventional carbon energy carriers. One of the problems of effective development of agricultural engineering is flexibility in managing the production process, which is extremely important in a globalised economy. Based on the product-service system (PSS), C. Kolling *et al.* (2022) proposed a conceptual model for the implementation of a product-oriented life cycle management system for agricultural machinery, which allows its producers to expand their understanding of the "product-service" system and promote sustainable production of machinery, in accordance with changing consumer requirements.

In the context of Ukraine's declared desire to integrate into European and world economic institutions, to participate in the global division of labour, these problems and challenges increasingly affect the development of Ukrainian agricultural engineering. Accordingly, the purpose of the study was to analyse current trends in the development of the industry in order to work out effective measures for its restoration and further innovative development in the post-war period.

## ► Materials and Methods

The analysis of the state of agricultural machinery production, its export potential, and prospects for its development in the post-war period in Ukraine on a scientific basis is reflected in the corresponding methodological approach. The methodological basis of the research is the dialectical method of cognition and a systematic approach to studying the development of agricultural machinery production for crop farming in Ukraine. The following

methods of scientific cognition were used. Data analysis was used to highlight the views of researchers on the issues and problems considered in the paper. Economic and statistical – was used in the process of analysing export operations and profitability, and reflecting the dynamics of the availability of enterprises and the availability of employees. Tabular and graphical methods were used to visually display the results of the study in the form of figures and tables. The analysis and synthesis were used to investigate the state of Ukrainian agricultural engineering during the war period. The comparative analysis was used in the process of determining the main problems of development of the agricultural engineering industry. The analytical forecasting was used to determine tasks and recommendations for the development of the industry in the post-war period. The abstract logical method was used to generalise and formulate conclusions.

The statistical method was used to study the influence of factors of foreign economic activity, forecasting the situation on the agricultural machinery market in the post-war period. The characteristics of export operations change over time, and indicators of dynamics series are used to assess their intensity. To obtain absolute growth, a chain analysis method was used – comparing the number of active enterprises and their growth or decline due to the impact of war on regions. The index method was used to analyse the level of revealed comparative advantages (RCA) of agricultural engineering products in different countries. The indicator was calculated using the equation:

$$RCA = (X_{ij}/X_i)/(X_{nj}/X_n), \quad (1)$$

where  $X_{ij}$  – export of goods  $j$  from the country  $i$ ;  $X_i$  – total export of the country  $i$ ;  $X_{nj}$  – total export of goods  $j$  in the world;  $X_n$  – total exports of the world's countries. In other words, the index shows the ratio of the share of a product (industry) in national exports to the share of this product in world exports.

Correlation and regression analysis was used to determine the close relationship between export volumes and tractor production, the level of dependence of changes in the effective feature (tractor production volumes) on the influence of the factor feature (export volumes). The information base of the study was the papers by Ukrainian (Boltyanskaya & Boltyansky, 2020; Navrotskyi & Petrov, 2023) and foreign researchers (Ruffoni & Reichert, 2022). The methodological basis was also provided by reference and information publications, statistical and analytical data from the Ministry of Agrarian Policy has disclosed data on UAH 13 billion of state support over the past three years (2021) for 2020, as certain data has not yet been made public or is not available, Activities of enterprises (n.d.), BI – Foreign trade indicators of Ukraine (n.d.).

### ► Results and Discussion

The regional location of agricultural engineering enterprises in Ukraine has historically been based on the principles of economic feasibility. The availability of raw materials (primarily suppliers of metal components), energy and water resources, appropriate labour potential and developed agricultural production determined the location of most equipment manufacturers in the southern, eastern, and central regions of the country (Table 1).

**Table 1.** Location of agricultural engineering enterprises in Ukraine in 2020

Oblast	Legal entities, units	Individual entrepreneurs, units	Individual entrepreneurs, %
Zaporizhzhia	74	46	38.3
Kharkiv	40	27	40.3
Dnipropetrovsk	54	7	11.5
Kirovohrad	31	12	27.9
Kyiv city	35	4	10.3
Vinnitsia	24	11	31.4
Kyiv	21	12	36.4
Zhytomyr	20	7	25.9
Cherkasy	16	11	40.7
Khmelnitskyi	11	14	56.0
Poltava	14	11	44.0
Odesa	16	3	15.8
Lviv	12	6	33.3
Mykolaiv	13	5	27.8
Sumy	11	3	21.4
Kherson	8	5	38.5
Chernihiv	8	1	11.1
Luhansk	3	2	40.0
Ivano-Frankivsk	3	1	25.0
Ternopil	1	3	75.0
Zakarpattia	3	1	25.0

Table 1, Continued

Oblast	Legal entities, units	Individual entrepreneurs, units	Individual entrepreneurs, %
Rivne	3	0	0.0
Volyn	0	2	100.0
Chernivtsi	1	0	0.0
Donetsk	0	0	0.0
Total	616	194	31.5

Source: developed by the authors based on Activities of enterprises (n.d.)

The western region is less saturated with machine-building enterprises (for example, in the Zakarpattia and Rivne oblasts there are only three enterprises, in Volyn – two, and in Chernivtsi – only one). This is conditioned by the distance from the raw material (metallurgical) base and a significantly lower level of concentration of agricultural production (primarily crop production) compared to other regions. However, with the outbreak of hostilities, it was the eastern and southern regions with the most developed agricultural machinery that were either under occupation or became frontline territories, which practically paralysed the activities of industrial enterprises and continues to lead to their physical destruction as a result of deliberate targeting by the aggressor. A significant proportion of agricultural machinery manufacturers in

Ukraine are registered as individual entrepreneurs whose income is limited by tax legislation (Tax Code of Ukraine..., 2010). Based on the data in Table 1, most of them are in Khmelnytskyi – 14 (56%), Poltava – 11 (44%), Cherkasy – 11 (41%) and Kharkiv – 27 (40%) oblasts. In the Volyn Oblast, both registered enterprises are individual entrepreneurs, and in the Ternopil Oblast – three out of four.

The dynamics of the number and share of agricultural machinery producers in Ukraine in terms of production concentration indicates the dominance of the category of microenterprises (Table 2). Their share in 2010 was 81.4% of all agricultural engineering enterprises, but by 2020-2021 it decreased, respectively, to 61.3 and 68.5%. In general, the share of small businesses in the industry in 2021 was 91.5%.

Table 2. Number and share of agricultural engineering enterprises by individual categories in Ukraine

Years	Large enterprises		Medium-sized enterprises		Small enterprises		of these, microenterprises		Total, units
	units	%	units	%	units	%	units	%	
2010	3	0.4	61	8.2	683	91.4	608	81.4	747
2011	2	0.3	70	10.3	608	89.4	507	74.6	680
2012	3	0.7	60	13.5	381	85.8	272	61.3	444
2013	2	0.4	50	11.1	398	88.5	278	61.8	450
2014	2	0.4	47	9.8	430	89.8	318	66.4	479
2015	2	0.4	48	9.6	450	90.0	348	69.6	500
2016	1	0.2	55	10.4	473	89.4	370	69.9	529
2017	0	0.0	66	12.1	479	87.9	363	66.6	545
2018	0	0.0	66	11.8	495	88.2	378	67.4	561
2019	0	0.0	64	10.8	527	89.2	399	67.5	591
2020	0	0.0	56	9.1	560	90.9	427	69.3	616
2021	1	0.2	52	8.3	573	91.5	429	68.5	626

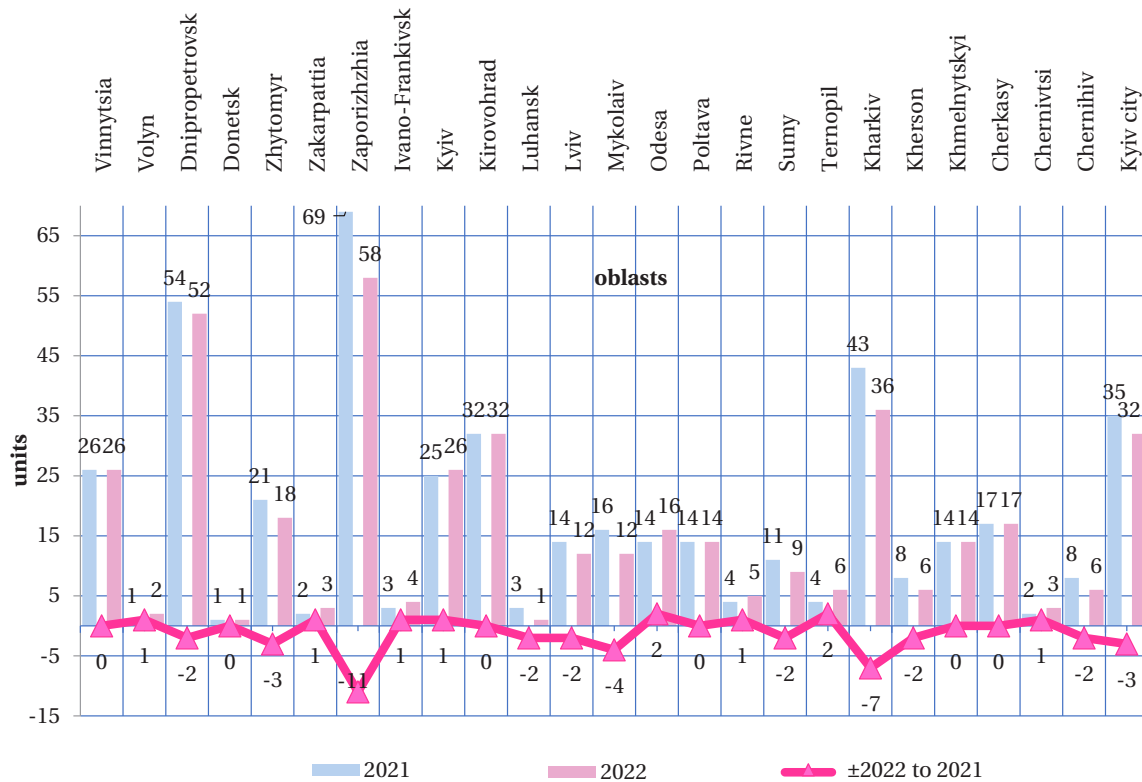
Source: developed by the authors based on Activities of enterprises (n.d.)

Due to the low level of concentration of resource potential (production, technological, financial, investment, intellectual, labour) small enterprises are unable to ensure the production of modern complex innovative means of mechanisation of agricultural production. Their activities are aimed at manufacturing, as a rule, small batches of non-complex machines and tools, spare parts or components for complex equipment, and introducing large-unit assembly of individual modifications of machines or technological complexes (Datsenko, 2019).

In 2021-2022, there were significant changes in the territorial distribution of agricultural machinery

producers in Ukraine. Naturally, in the southern and eastern regions, which were most affected by military operations, the number of machine-building enterprises decreased. In Zaporizhzhia, Kharkiv, and Mykolaiv oblasts, this decrease was 11, 7 and 4 units, respectively. Some enterprises were relocated to the western and central regions (Volyn, Zakarpattia, Ivano-Frankivsk, Kyiv, Odesa, Ternopil, Chernivtsi oblasts), some simply stopped operating due to various circumstances.

In general, during the year of military operations, the number of active enterprises in the industry decreased by 30 units (Fig. 1).



**Figure 1.** Number of active agricultural engineering enterprises by regions of Ukraine in 2021-2022 as of November 1, units

**Source:** developed by the authors based on the Register of statistical units (n.d.)

According to the level of concentration of labour potential among agricultural machinery manufacturers in Ukraine, the leading positions are traditionally occupied by large and medium-sized enterprises (Table 3).

**Table 3.** Number of employees at agricultural engineering enterprises in Ukraine

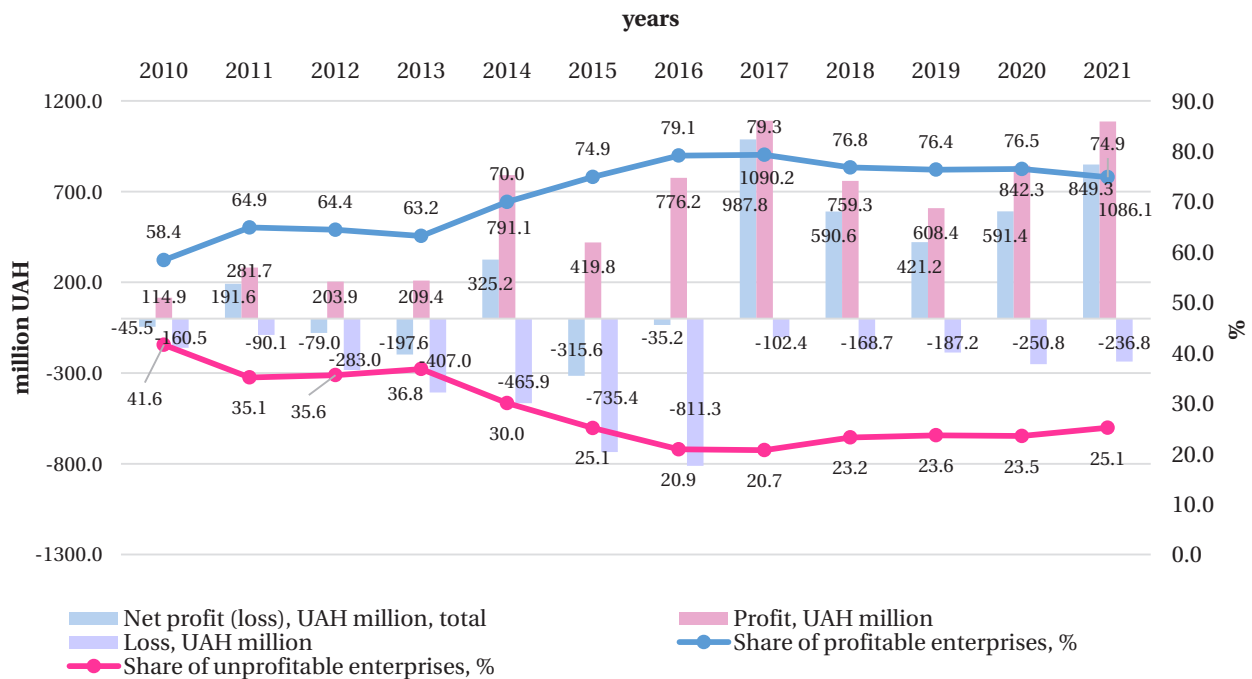
Years	Total, persons	Business categories							
		large		medium		small		of these, microenterprises	
		persons	%	persons	%	persons	%	persons	%
2010*	24 893	6472	26.0	14 705	59.1	3716	14.9	1460	5.9
2011	–	c	c	15 308	62.8	c	c	1385	5.7
2012	23 542	4523	19.2	15 260	64.8	3759	16	802	3.4
2013	–	c	c	c	c	3752	19.4	728	3.8
2014	–	c	c	c	c	3700	20.2	852	4.7
2015	–	c	c	c	c	3245	16.5	913	4.6
2016*	19 084	592	3.1	15 128	79.3	3364	17.6	923	4.8
2017	–	0	0	c	c	c	c	969	4.7
2018	–	0	0	c	c	c	c	1122	5.4
2019	–	0	0	c	c	c	c	1031	5.8
2020	16 615	0	0	12 250	73.7	4365	26.3	1067	6.4
2021	–	c	c	c	c	4843	28.9	1147	6.8

**Note:** c – data are not disclosed to ensure compliance with the requirements of the Law of Ukraine No. 2614-XII “On State Statistics” (1992) regarding the confidentiality of statistical information; \* – estimated total employment and employment at large enterprises

**Source:** developed by the authors based on Activities of enterprises (n.d.)

As of 2023, it is difficult to conduct a thorough analysis of the relevant data due to the limited amount of statistical information in the public domain. But the published data indicate that the share of employees at large and medium-sized enterprises in 2010-2021 was at the level of 71-85%. The number of employees in the industry in the study period decreased by 8278 people (33.3%). The tendency to reduce employees at agricultural engineering enterprises

and the growth of their share in small companies indicates an overall decrease in production volumes at them (in particular, high-tech and innovative products), loss of competitive positions of Ukrainian machine-building products on the market, and simplification of the technological process. The analysis of indicators of economic efficiency of agricultural engineering enterprises in Ukraine for 2010-2021 suggests the instability of the industry's development (Fig. 2).



**Figure 2.** Dynamics of profitability (unprofitability) of agricultural engineering enterprises in 2010-2021

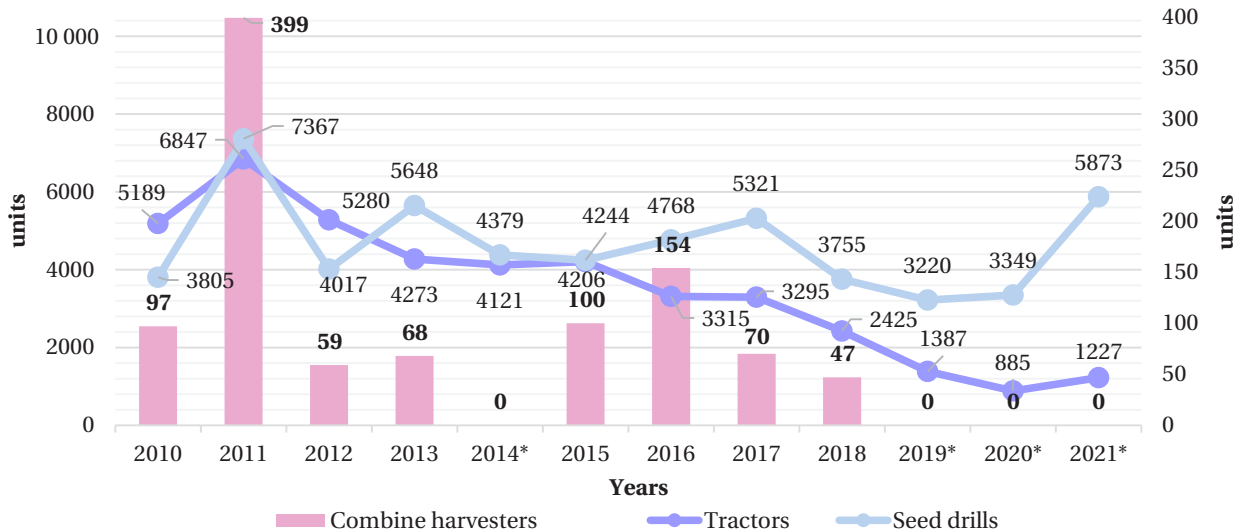
**Source:** developed by the authors based on Activities of enterprises (n.d.)

Over the 12 years of observation, five agricultural machinery companies have made a loss in total. One of the factors of growth in the profitability of the industry in 2017-2021 was the implementation in Ukraine from 2017 of the national programme of partial compensation for the cost of agricultural machinery and equipment of domestic production, which stimulated the growth of production of machine-building products and their sale to rural producers (Resolution of the..., 2017). The programme became a small example of a more or less effective mechanism of state support for agriculture and industrial engineering during the time of independence (Farmers are asking..., 2022) and allowed Ukrainian agricultural machinery to slightly improve its position in the domestic market.

The independent Ukraine inherited from the former USSR a powerful machine-building complex for the production of agricultural machinery and equipment: in 1991, the Ukrainian industry produced 90.2 thousand tractors, 71.9 thousand ploughs, and 48.7 thousand seed drills (Samchenko, 1992). The general economic crisis caused by the collapse of the then unified national economic complex, the loss of inter-republican economic ties, outdated production technologies and, accordingly, the low competitiveness of Ukrainian equipment in foreign markets, the import of foreign high-quality machinery and equipment led to the decline and loss of powerful production

potential, which until recently allowed the development and production in Ukraine of fully equipped technological complexes for crop and livestock production. The level of localisation of Ukrainian complex agricultural machinery is quite low – machinery and equipment are equipped with foreign-made components and assemblies.

In Ukraine, there is historically no culture of production of self-propelled combine harvesters, so state funding for development work on their design and establishment of mass production has not led to positive results. Attempts to establish the production of licensed machines or create joint ventures with leading Western manufacturers of relevant machine-building products are not successful, primarily due to unbalanced state policies and weak control over the use of budget funds. As a result, the Ukrainian market is saturated with imported combines. New machines of the world's best brands and used combine harvesters in the secondary market actively compete with each other in the market. Only a small number of harvesting machines assembled in Ukraine from foreign components were in demand due to the state programme of partial compensation for the cost of machinery and equipment of domestic production. During 2010-2021, in 2011 alone, the output of combine harvesters amounted to 399 units, but this is only 15.2% of the 2619 units imported in that year (Fig. 3).



**Figure 3.** Production of certain types of agricultural machinery in Ukraine, units

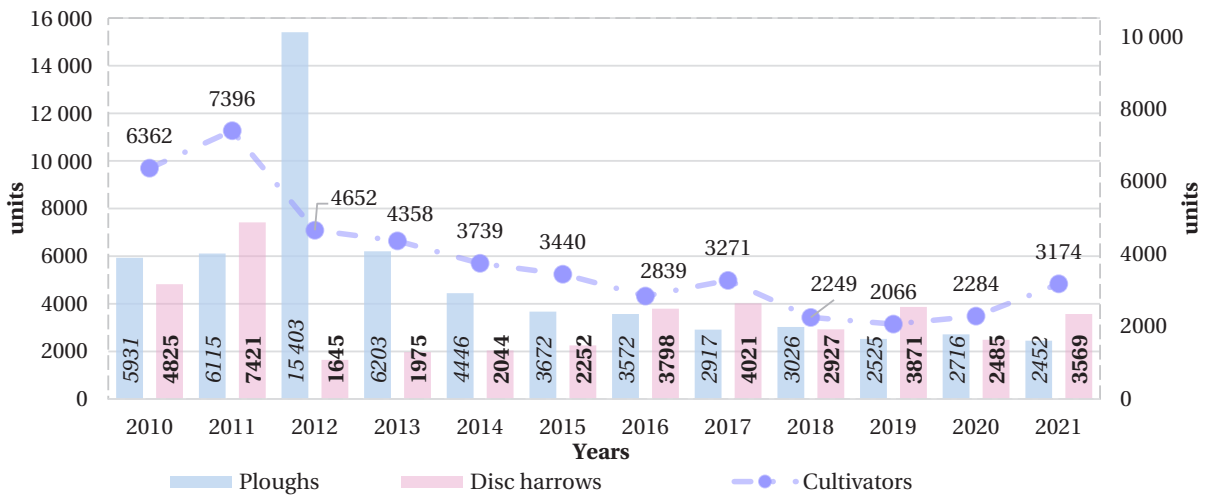
**Note:** \* – the data is confidential in accordance with the Law of Ukraine No. 2614-XII “On State Statistics” (1992)

**Source:** developed by the authors on based on data Activities of enterprises (n.d.)

During 2011-2021, tractor production in Ukraine decreased by 5-8 times. The gradual reduction of the market for power vehicles in the Russian Federation and its complete loss since 2019, together with their low competitiveness in comparison with foreign analogues, significantly limited the export opportunities of the Ukrainian tractor machinery industry. The production of various types of seed drills remains relatively stable in Ukraine (in 2010-2021, respectively, 3.2-5.9 thousand units), which is

identified primarily with the flagship of domestic agricultural engineering.

The segment of the tillage equipment market is promising from the standpoint of meeting the needs of Ukrainian production. The vast majority of types of tillage machines and tools are not complex, their production does not require large capacity, advanced technologies and qualified engineering and technical personnel (Fig. 4).



**Figure 4.** Dynamics of production of tillage machines and tools in Ukraine, units

**Source:** developed by the authors based on data from Activities of enterprises (n.d.)

During 2010-2021, the production of ploughs, disc harrows, and cultivators of various types in Ukraine has relatively stabilised, which gives grounds to assert that the market is sufficiently saturated with them and, accordingly, meets the demand of rural producers. The shift in the market segment of tillage machines and tools is significantly affected by the intensive introduction of modern alternative technologies of soil-free tillage in agricultural enterprises (Prymak *et al.*, 2018). Consequently, the demand for

shelf ploughs is decreasing, while the demand for disc, flat-cutting, chisel, and other types of tools that work without rotating the chaff is growing. The high export potential of agricultural engineering in any country indicates the use of modern innovative technologies in production and high competitiveness of products. To assess the export potential, the RCA index is used, which is internationally used to calculate the relative advantages or disadvantages of a country in a particular market segment (Table 4).

**Table 4.** Index of revealed comparative advantages of certain types of agricultural machinery in 2021

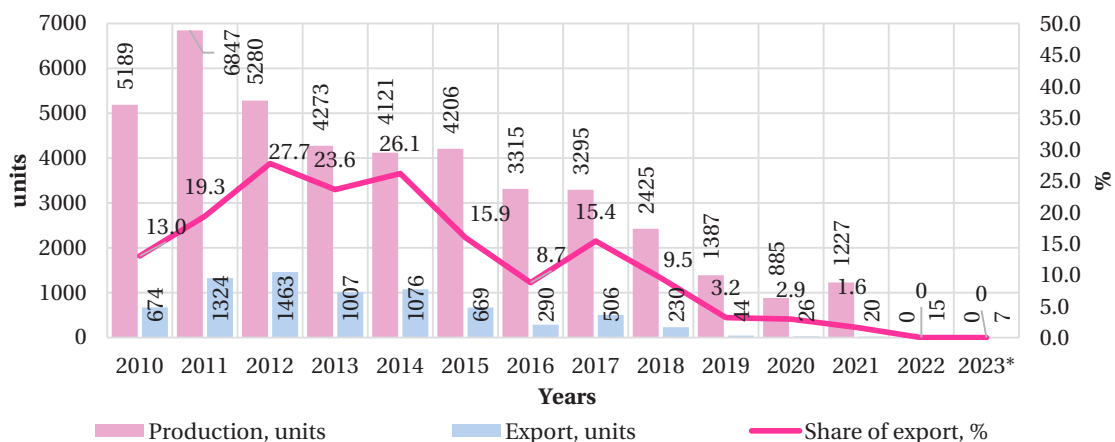
Country	Equipment type		
	tillage equipment	harvesting equipment	tractors
Ukraine	1.802	0.273	0.034
Belarus	3.957	4.601	5.900
Kazakhstan	0.058	0.024	0.020
Moldova	0.467	0.278	0.020
Poland	1.967	2.693	1.411
Czech Republic	2.772	1.957	0.379
France	1.967	1.886	2.561
Italy	3.451	2.251	1.253
Germany	2.500	2.439	2.182
USA	0.856	1.694	1.008
Argentina	0.476	0.411	0.005
Brazil	1.319	1.116	1.744
India	1.093	0.217	1.182
China	0.692	0.867	0.260

**Source:** developed by the authors based on World trade (n.d.)

The index value from 0 to 1 indicates a low level of competitive advantages of products in international markets. In 2021, Ukraine had a fairly high level of competitive advantages only in terms of tillage equipment (including sowing equipment) – 1.802; the lowest indicator for tractors – only 0.034. The CIS countries – Moldova and Kazakhstan – also have low indicators. Belarus has quite high indicators of the RCA index. It was able to maintain its production and export potential due to the simplicity of its agricultural machinery. Italy (3.451), the Czech Republic (2.772), and Germany (2.500) are the leaders in tillage equipment; Poland (2.693), Italy (2.251), and Germany (2.439) are the best performers in harvesting machines; and France (2.561), Germany (2.182), and Brazil (1.744) have the highest competitive advantage in tractors. The relatively low index of competitive advantages of US products is explained by the location of industrial capacities of agricultural machinery manufacturers in Germany, Poland, Italy, France, etc., which contributes to the growth of the RCA index in these countries. The

low (significantly less than 1.0) level of competitive advantages of Chinese-made equipment is explained by its relatively low consumer characteristics and the focus of mostly rural producers with a low level of concentration of agricultural production. However, in the period from 2013 to 2023, the country has seen a steady trend towards improving the quality and expanding the range of machines, including those for use on large areas.

The correlation analysis of the relationship between tractor production and export in 2010-2021 clearly indicates that it is quite high ( $r=0.8982$ ) and approaches very high on the Cheddock scale (Kushnir & Zavalnyuk, 2018). Value of the coefficient of determination ( $R^2=0.8069$ ) indicates a high dependence of changes in the effective attribute, which is production volumes, on the influence of the factorial attribute (in this case, export volumes) (Fig. 5). These data clearly show that in Ukraine, with a decrease in export volumes (demand on foreign markets), tractor production volumes adequately decrease.

**Figure 5.** Production and export of tractors in Ukraine

**Note:** 2022-2023 – there are no statistics on tractor production; \* – for January-July 2023

**Source:** developed by the authors based on data from Activities of enterprises (n.d.); BI – Foreign trade... (n.d.)

The main importer of Ukrainian tractors before the relevant ban in 2019 was the Russian Federation. During 2010-2018, the share of exports of Ukrainian tractors to this country was 75.0-97.2% (maximum in 2017 – 492 units). That is, export flows of this type of agricultural machinery were mainly directed to one regional market, while deliveries to the markets of other countries occurred in very limited volumes. In general, over the

past ten years, Ukraine has supplied tractors of its own production to Armenia, Georgia, Kazakhstan, Congo, Cuba, Moldova, Poland, and Romania (Activities of enterprises, n.d.; BI – Foreign trade..., n.d.). The export of Ukrainian-made sowing equipment is more diversified than the export of tractors. However, the main importer of Ukrainian sowing machines until 2019 was also the Russian Federation (Table 5).

**Table 5.** Exports of seed drills, planters, and seedling planting machines from Ukraine

Years	Countries													
	Russia		Kazakhstan		Moldova		Belarus		Poland		Romania		USA	
	units	%	units	%	units	%	units	%	units	%	units	%	units	%
2010	1403	80.2	135	7.7	85	4.9	–	–	–	–	–	–	–	–
2011	2985	84.5	170	4.8	165	4.7	–	–	–	–	–	–	–	–
2012	1381	71.4	144	7.4	121	6.3	–	–	–	–	–	–	–	–
2013	1652	67.1	220	8.9	–	–	322	13.1	–	–	–	–	–	–
2014	1503	46.8	–	–	641	20.0	679	21.1	–	–	–	–	–	–
2015	1706	37.1	–	–	1707	37.1	582	12.7	–	–	–	–	–	–
2016	1933	28.2	–	–	3259	47.5	1207	17.6	–	–	–	–	–	–
2017	2463	27.2	–	–	4354	48.2	1897	21.0	–	–	–	–	–	–
2018	2646	34.0	–	–	4451	57.2	434	5.6	–	–	–	–	–	–
2019	–	–	–	–	4549	52.3	1744	20.1	–	–	1999	23.0	–	–
2020	–	–	186	6.3	168	5.7	2221	75.7	–	–	–	–	–	–
2021	–	–	–	–	1276	28.5	1665	37.1	–	–	–	–	540	12.0
2022	–	–	–	–	1282	25.5	–	–	604	12.0	–	–	2220	44.2
2023	–	–	141	8.3	1079	63.4	–	–	140	8.2	–	–	–	–

**Note:** 2023 – January-July

**Source:** developed by the authors based on data from Activities of enterprises (n.d.); BI – Foreign trade... (n.d.)

The positive trend in exports of Ukrainian sowing machines to the US is noteworthy. In 2021-2022, 540 and 2220 seed drills of various designs were delivered to this country, respectively, which accounted for 12.0 and 44.2% of the total volume of their deliveries to foreign markets. The development of such a complex balanced market by Ukrainian industrial machine-building enterprises gives every reason to state the high level of competitiveness of their products and favourable opportunities for expanding the geography of export supplies, primarily to the countries of Eastern and Western Europe, the Baltic states, etc. As of 2023, the development of industrial enterprises of agricultural engineering in Ukraine is extremely negatively affected by large-scale military operations. A significant part of the production capacity of the industry's enterprises has been destroyed, damaged, under occupation or located in a war zone. Economic factors of negative impact on their production activities also traditionally remain inflationary processes, disruption of logistics links and cooperation with suppliers, rising prices for energy resources, problems with qualified personnel, etc.

Kharkiv Tractor Plant, a leading domestic manufacturer of tractors, already suffered significant destruction at the beginning of the war and lost 75% of its value – from USD 40 million to USD 10 million (The value of Yaroslavsky's..., 2022). Berdyansk "John Greaves" plant,

specialising in the production of harvesters for various crops, was occupied, and today its production facilities are being re-profiled to meet the needs of the enemy army (Who got the..., 2023). The city-forming plant "Orikhivsil-mash", which was located in the war zone and received significant damage, was relocated to Zaporizhzhia in time and partially resumed its work (Zaporizhzhia company..., 2022). A significant reduction in the production of Ukrainian machinery will lead to a decrease in its presence on the domestic market, loss of export potential and restriction of access to cheap domestic machinery by rural producers.

Given the negative impact of the war, the further development of Ukrainian agricultural engineering will face complex systemic problems, which will be impossible to overcome without active state assistance. As a result of the physical destruction and damage, a number of high-tech enterprises are expected to be irretrievably lost, and their restoration will require large investments, both private and public. Due to forced migration and departure to the Armed Forces of Ukraine, as of 2023, there is an acute shortage of highly qualified engineers and workers in the industry, and this problem continues to deepen. Restoring broken logistics chains and supplier relationships will also require large organisational, managerial, financial, and other costs. Permanent growth in the cost of energy carriers will reduce the price competitiveness of domestic

agricultural machinery and tools in industry markets (NEURC revises electricity..., 2023).

Presented on 3 July 2023 by the Ministry of Agrarian Policy and Food, the presentation “Strategy for the development of the agro-industrial complex” envisages the construction of 2 motor machinery plants with a capacity of 1200 tractors and 300 combines, as well as 6 plants of mounted and trailed machinery with a capacity of 10 000 units per year, with investments of USD 720 million. Due to the new production, it is planned to replace imports by USD 1.2 billion and ensure the growth of export potential by USD 0.9 billion (Strategy for..., 2023). Given the capacity of the Ukrainian agricultural machinery market and projected export volumes, the planned measures are clearly insufficient. After all, in 2021 alone, Ukraine imported 30 318 tractors with a customs value of USD 574.3 million, 3029 combine harvesters (USD 283.8 million) and 85 022 units of the main types of mounted and trailed equipment for crop production (USD 323.6 million). In 2022, when part of the territories was already lost, 16 689 tractors (USD 314.4 million), 2104 combine harvesters (USD 177.4 million) and 53 227 units of other equipment (USD 156.9 million) were imported. Even during January-July 2023, Ukraine has already imported 7732 tractors (USD 164.8 million), 1329 combine harvesters (USD 100.8 million) and 21 551 units of other equipment (USD 106.6 million) (BI – Foreign trade..., n.d.). That is, the annual additional production of 1200 tractors compensates only 7.1%, 300 combine harvesters – 14.6%, 10 000 units of mounted and trailed equipment – 18.8% of imports in 2022. Therefore, it should be considered advisable to direct investments to the restoration, modernisation, and creation of joint ventures with the world’s leading manufacturers of agricultural machinery based on the existing production capacity of the industry. In addition, it is worth resuming the programme of partial compensation for the cost of agricultural machinery and equipment of domestic production, which was suspended due to the outbreak of hostilities in 2022. After all, due to this programme, in 2017, 1220 enterprises purchased 2906 units of equipment for a total of UAH 670.28 million; in 2018, 7043 enterprises purchased 17 182 units of agricultural machinery and equipment for the amount of UAH 3 651.76 million; in 2019, 9508 farms took part in the programme, a total of 25 075 units of equipment with a total cost of UAH 5 786.2 million; in 2020, 7260 enterprises purchased 14 946 units of equipment worth UAH 4 331.92 million; 2021 was also successful for both manufacturers of equipment and its consumers – 5789 agricultural enterprises purchased almost 30 thousand machines (Ministry of Agrarian..., 2021).

To overcome the negative consequences of the impact of the war on the development of the agricultural machinery industry, the state must create favourable investment conditions and implement a number of measures. The implementation of a balanced protectionist customs policy will allow, on the one hand, to protect the domestic producer of agricultural machinery, and on the other – to ensure the unhindered import of machinery and equipment that belongs to the category of critical imports, for example, combine harvesters. Creating a favourable investment climate and simplifying business conditions should be carried out not only during the war, but also after its end.

This will provide prerequisites for attracting external and internal investment in the restoration, reconstruction, and development of new enterprises for the production of equipment for rural areas, including through the organisation of joint ventures with the world’s leading manufacturers. Providing tax holidays and tax benefits for industry enterprises not only for the duration of recovery, but also for the time of reaching the project capacity will give an impetus to their active development and attract additional sources of investment. The relocation of industrial enterprises from the war zone to safe regions will allow preserving not only production, but also personnel potential. A striking example of this approach is the evacuation of the “Orikhivsilmas” enterprise to Zaporizhzhia and the resumption of its operation in a short time (Navrotskyi & Petrov, 2023; Yevtushenko *et al.*, 2022).

The negative factors caused by the war for the development of the agricultural machinery industry include inflation, disruption of logistics chains, loss of ties with suppliers, high prices for energy resources, and personnel problems. The destruction and occupation of a significant part of the industry’s enterprises also have a negative impact on the effectiveness of their development. To overcome the negative consequences of the impact of military operations on the further development of agricultural machinery in Ukraine, it is necessary to implement the following measures: restore the state programme of partial compensation for the cost of agricultural machinery and equipment of domestic production; implement a protectionist customs policy at the state level; create a favourable investment climate and simplify business conditions; introduce a preferential taxation regime for enterprises of the industry during their recovery and reaching their design capacity; evacuate enterprises from the war zone to safe regions; constantly carry out measures to preserve the personnel potential of the industry. The proposed measures will contribute to the restoration of the agricultural machine-building complex of Ukraine, the introduction of innovative production technologies, and improving its quality to the level of the best world samples, which will increase the export potential of the industry and develop new markets for domestic agricultural machinery.

The statement of V.V. Nekhai & O.V. Kravets (2022) regarding the need to build several single-sector technologically related enterprises on the basis of agricultural machinery enterprises of Ukraine to jointly create a customer value chain, promote and sell goods and services, manage customer relations through a single, separate coordination centre that implements an integrated strategic marketing and sales policy on behalf of and at the expense of all participating companies is considered debatable. In fact, the authors propose the creation of cartels. Although there is no such term in Ukrainian legislation, there is a similar one – “anticompetitive concerted actions”, which are actions that have led or may lead to the prevention, elimination or restriction of competition. The commission of anticompetitive concerted actions is prohibited and entails liability under the Law of Ukraine No. 2614-XII “On State Statistics” (1992). In order to increase the competitiveness of industry products, increase their sales volumes, increase export potential and expand sales markets, it is necessary to introduce international standards of quality,

safety, and environmental friendliness at enterprises. The transition to international production standards allows equipment manufacturers, including Ukrainian ones, to maintain and expand their presence in the domestic market and develop new foreign markets (Vidosa *et al.*, 2022). For example, harmonisation of standards for the production and trade of tractors contributes to the growth of sales volumes between countries, as it reduces duplication of tests in foreign markets, reduces transaction costs in the process of resolving trade disputes, improves the risk management of producers and positively affects the growth of demand of agricultural producers through trust in internationally certified products.

One of the priority tasks of the agricultural machine-building complex is customer orientation, which implies high reliability, safety, environmental friendliness, ergonomics, and cost-effectiveness of products. F. Grandi *et al.* (2018) use the term “perceived quality”, which implies human orientation through the aesthetic design of equipment, optimal performance characteristics, high reliability, ease of use, availability, cost, etc. M. Fagnoli & M. Lombardi (2020) substantiated the need for the most human-centred approach to addressing tractor safety issues. One of the factors contributing to the problem is the lack of a unified, reliable system of technical standards. The researchers investigated the need to upgrade the ROPS system (rollover protection system) on older tractors. P. Gupta & A. Mittal (2021) analysed the activities of a tractor manufacturer that lost its position in the market, but due to total quality management (TQM) optimisation, it was able to restore them. Increasing the level of customer satisfaction has become one of the main goals for the company, which increased the competitiveness of products that the Ukrainian equipment manufacturer lacks.

To successfully promote products on the market and meet the needs of customers, it is necessary to innovate the development of the enterprise and its adaptability to the rapidly changing market requirements. The authors agree with the opinion of E.P. Ruffoni & F.M. Reichert (2022), who determined that rural machinery manufacturers innovate through the use of two combinations of possible expansion: development, operational activities and management, or operational activities and transactions. According to the researchers, innovation is possible only if you supplement production excellence by improving existing products and management processes, or by improving negotiation skills and commercialisation processes. For implementation in the field of agricultural engineering of Ukraine, the paper by P. Niewiadomski *et al.* (2019) is aimed at determining the level of maturity of technical culture in enterprises. The criterion for the maturity of technical culture is compliance with the principles of lean production. The developed methodology can be useful for the self-assessment and orientation of enterprises seeking to increase maturity and implement lean manufacturing.

In continuation of the theme of the maturity of technical culture, B. Nogalski *et al.* (2020) argue that mature enterprise business models must adapt quickly to unexpected and unpredictable market changes. The researchers justify the expediency and purposefulness of implementing such business models at the enterprise, which is aimed at the strategic perspective of adaptation

to the market. The need for this adaptation is dictated by the specifics of high competition in the agricultural machinery market at the local, national, and international levels. N.I. Boltyanskaya & O.V. Boltyansky (2020) argue that almost half (about 38%) of Ukrainian-made equipment does not meet the regulatory and technical requirements during testing, more than 63% of tested machines fail within 10-100 hours, and 16% of equipment does not meet the requirements of occupational safety. Before the start of full-scale military operations in 2022, a significant number of enterprises actively introduced innovations in production and improved the quality of their products. Thus, at the end of 2019, “Elvorti”, a company that produces tillage and sowing equipment, entered the top 50 innovative companies in Ukraine due to the use of Toyota’s lean manufacturing principles. The company’s savings from reducing electricity and heating costs amounted to about UAH 1.5 million per year (TOP-50 innovative..., 2019). Kharkiv Tractor Plant aimed to create a powerful industrial park on its own production base, the key resident of which was to be KHTZ. The technopark’s activities were also aimed at developing IT technologies, logistics, trade, educational and other clusters (Employees of Kharkiv..., 2022). At the present stage of development of the agricultural machinery industry in Ukraine, its products are mostly not competitive in comparison with the products of the world’s best manufacturers, strong production and human resources potential, investments and state assistance will allow it to reach the appropriate level.

### ► Conclusions

The regional location of agricultural engineering enterprises is based on the principles of proximity to the raw materials and energy base, human resources and sales markets, that is, most of the enterprises are located in the eastern and southern regions – Zaporizhzhia (120 units), Kharkiv (67 units), and Dnipropetrovsk (61 units). The largest share of individual entrepreneurs is in Khmelnytskyi (14 enterprises, 56.0%), Poltava (11 enterprises, 44.0%), Cherkasy (11 enterprises, 40.7%) and Kharkiv (27 enterprises, 40.3%) oblasts. The majority of enterprises in the industry are classified as “small” – from 85.8% in 2012 to 91.5% in 2021, and the majority of employees in the industry are employed in “medium” enterprises – from 59.1% in 2010 to 79.3% in 2016. There is a general tendency to reduce the number of employees in agricultural engineering enterprises and increase their share in small enterprises, which leads to a decrease in the volume of equipment production and deterioration of its quality. Military operations caused a decrease in the number of active enterprises by 30 units as of November 1, 2022, compared to their number as of November 1, 2021.

A study of the dynamics of profitability of enterprises in the industry indicates a low efficiency of its activities. In general, the industry was unprofitable until 2016 – total losses amounted to UAH 35.6 million. The main factor behind the industry’s profitability growth was the introduction in 2017 of a partial compensation programme for the cost of domestically produced agricultural machinery and equipment, which significantly increased sales and, consequently, profit – in 2021, the industry’s profitability was UAH 849.3 million. Due to the lack of production potential,

Ukraine is not able to provide its own agricultural production with combine harvesters – with the import of 3229 units in 2017, its own production was only 70 units. The most promising for the Ukrainian agricultural engineering industry is the production of seed drills – the maximum volume of their production was 7367 units in 2011, and the minimum – 3220 units in 2019. The production of sowing machines in Ukraine has a strong export potential and a greater level of diversification in the markets than other types of equipment. After 2019, export flows were directed to the United States – 2220 units (44.2%) in 2022 and to Moldova – 1079 units (63.4%) in 7 months of 2023.

The production of tillage equipment mainly does not require innovative technologies and highly qualified personnel. The maximum production volumes of this type of equipment were observed in 2011 – 15 403 ploughs, 7421 disc harrows, and 7396 cultivators. There is a general tendency to reduce the production of plows due to the active introduction of dump-free technologies. In 2021, Ukraine experienced a fairly high level of competitive advantages

only in relation to tillage equipment (including sowing equipment) – 1.802, the lowest indicator for tractors – only 0.034. The correlation between tractor production and export for the period 2010-2021 is high ( $r=0.8982$ ). The coefficient of determination  $R^2=0.8069$  indicates a high dependence of tractor production volumes on their export volumes.

The prospect of further study is to investigate the sale of agricultural machinery as an important element of market relations. The study will include an analysis of the activities of enterprises and structures that sell equipment and its service, the effectiveness of their activities and the impact on the field of war sales, and determining ways to develop trade in the post-war period.

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#### ► Conflict of Interest

The authors declare no conflict of interest.

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## Виробництво як ланка ринку сільськогосподарської техніки для рослинництва України

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► **Анотація.** Виробництво сільськогосподарської техніки та обладнання в Україні є одним з основних джерел наповнення ринку матеріально-технічних ресурсів для аграрного виробництва, але станом на 2023 рік не повною мірою задовольняє його потреби. Відповідно до актуальності порушеної проблеми, метою роботи було дослідження тенденцій розвитку галузі сільськогосподарського машинобудування в Україні у динаміці, впливу на нього воєнних дій та опрацювання ефективних шляхів подолання їх негативних наслідків. У процесі дослідження були використані наступні методи: діалектичний, статистико-економічний, графічний, індексний, кореляційно-регресивного аналізу, емпіричний, порівняльного аналізу, аналітичного прогнозування, абстрактно-логічний тощо. Визначено принципи регіонального розміщення підприємств сільськогосподарського машинобудування залежно від наявності сировинної бази, енергетичних та трудових ресурсів. Визначено структуру підприємств галузі за категоріями – більшість з них складають малі підприємства (85,8-91,5 %), але більшість працівників припадає на середні підприємства (59,1-79,3 %). Через військові дії кількість активних підприємств галузі скоротилася приблизно на 30 одиниць. Виявлено тенденцію щодо скорочення виробництва в Україні тракторів, комбайнів та деяких видів ґрунтообробних машин та причини його виникнення. Обґрунтовано перспективність виробництва в Україні техніки для посіву. Проаналізовано індекс виявлених порівняльних переваг різних країн за окремими видами техніки, виявлено, що в Україні лише техніка для обробки ґрунту має високий рівень переваг – 1,802 та має оптимістичні перспективи розвитку. У роботі визначено тісний кореляційний зв'язок між експортом та виробництвом тракторів в Україні у 2010-2021 рр. (відповідний коефіцієнт кореляції склав 0,8982). Встановлено проблеми, що гальмують розвиток галузі сільськогосподарського машинобудування: інфляція, порушення логістичних зв'язків та втрата постачальників, високі ціни на енергетичні ресурси тощо. Запропоновано рекомендації щодо їх подолання: створення сприятливих інвестиційних умов; здійснення протекціоністської митної та податкової політики для підприємств галузі; евакуація їх із зони бойових дій. Запропоновані заходи сприятимуть відновленню, збереженню та поступальному інноваційному розвитку потенціалу українського сільськогосподарського машинобудування

► **Ключові слова:** сільськогосподарське машинобудування; експорт; прибуток; розміщення підприємств; імпорт; ґрунтообробна техніка