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Ukrainian Black Sea Region Agrarian Science
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Prevention of degradation processes of soils irrigated with mineralized water through plastering

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Abstract. The long-term irrigation of extensive areas in the steppe zone of Ukraine using low-quality and mineralized water has caused degradation processes associated with soil salinization. To mitigate or alleviate these processes, researchers investigated the potential of chemical reclamation through the application of phosphogypsum. The study took place in the northern Steppe of Ukraine near the village of Oleksandrivka, Dnipro district, Dnipropetrovsk region. Over many years, field experiments were conducted, introducing phosphogypsum as a chemical meliorant. The experimental design included the application of phosphogypsum at rates of 1.4, 3.0, and 6.0 t/ha during different periods of the year. Standardized research methods were used for sampling, laboratory analysis, and processing of the results. The research identified a high salt content (0.35-0.48%) in

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the arable soil layer, signs of salinization (exchangeable sodium content of 3.64%), and unsatisfactory physical condition of the soil in the research areas. The application of phosphogypsum led to an increase in sulfate anions, as observed in the soil's sulfate chemistry, while the control areas exhibited a soda-sulfate type of salinity. The pH level of the water extract remained within neutral values throughout the years of the study. Positive changes were observed regarding the degree of soil salinity. Specifically, the application of phosphogypsum at rates of 3 and 6 t/ha in irrigated areas resulted in a change from moderate to slightly saline salinity levels. The research also demonstrated a positive effect on the sodium-adsorption ratio, particularly when phosphogypsum was applied during irrigation in the third year. The sodium-adsorption ratio decreased by 69% compared to the control options, indicating a better ameliorative effect of phosphogypsum during irrigation. Under the conditions of using water of class II quality for irrigation, the optimal application of phosphogypsum was found to be at doses of 3 t/ha for spring cultivation and 6 t/ha for the main cultivation in autumn. These application rates effectively reduced the degree of soil salinity and improved the ecological and meliorational conditions of the irrigated area

Keywords: land reclamation; irrigation; salinization; phosphogypsum; sodium-adsorption ratio; degree of salinity

INTRODUCTION

In contemporary agricultural practices, achieving reliable and consistent crop yields is unattainable without irrigation. While irrigation plays a vital role in enhancing agricultural productivity, it can also trigger unfavorable soil degradation processes. Prolonged irrigation with subpar water quality induces long-lasting alterations in the physical and mechanical properties of soils, as well as their salt composition.

Starting from the previous century, hydrotechnical land reclamation has been developed in Ukraine, resulting in about 5.5 million hectares of reclaimed land, with over 2.2 million hectares currently irrigated. However, due to inadequate exploitation, insufficient funding, and aging infrastructure, as of 2021, only 0.6 million hectares were irrigated. The long-term irrigation of large areas in the southern region of Ukraine with deteriorating water quality for more than 50-70 years caused soil degradation through salinization (Chornyy & Isaeva, 2023). To restore the meliorative systems and produce high-quality agricultural products, it is necessary to improve the ecological and meliorative state of irrigated soils. One potential solution to limit or mitigate the negative effects of salinization is to investigate the use of phosphogypsum in chemical reclamation, which is the focus of the research presented in the article.

The world practice of irrigation with mineralized surface and underground waters has shown that such irrigation is always accompanied by salinization of soils, leads to deterioration of their physical properties and a significant decrease in fertility. The use of gypsum as a chemical meliorant during irrigation with mineralized water is a long-known technique in the practice of irrigated agriculture, which is covered in many scientific works (McKenna *et al*., 2019; Makarova *et al*., 2021).

In Ukraine, studies on plastering of soils irrigated with mineralized waters were conducted by various scientists (Menshov & Kruglov, 2023). As a result of these studies, it was established that melioration by plastering increases the content of exchangeable and absorbed calcium and significantly reduces the amount of absorbed sodium. But even with high doses of gypsum, it is not possible to bring the degree of the soil solution saturation with calcium to the required level in the absence of watering. Ukrainian scientists, European and Asian researchers established patterns of changes in soil properties under the influence of irrigation and developed techniques to mitigate the adverse impact of poor-quality irrigation water on soils (Cuevas *et al*., 2019; Baliuk *et al*., 2021). Plastering and deep plantation plowing remain the most studied. Moreover, it was emphasized that plastering is a technique that limits or weakens the process of salting, but does not eliminate it completely (Bello *et al*., 2021)

Considering numerous scientific studies in the field of chemical melioration of irrigated soils and water, this problem remains insufficiently studied and relevant. Questions about the expediency and effectiveness of plastering chernozems with a weak degree of salinization remain unresolved. There are objections to the approaches to calculating doses of ameliorants and the quantitative component of the interaction of gypsum with soil and water is insufficiently covered. The ecological aspects of the ameliorants use have not been well developed, which necessitates the search for new, more effective measures from the point of view of resource and energy saving and environmental safety (Tsapko *et al*., 2017).

The need for chemical reclamation of irrigated lands is due to salinization of soils and their degradation –

compaction, destructuring, crust formation, etc. (Filipciuc *et al*., 2019). Irrigation with water of inadequate quality and non-compliance with the ecological components of farming cause the processes of soil degradation and the deterioration of the ecological and meliorative state of agricultural landscapes (Rudakov *et al*., 2020; Andrieiev *et al*., 2022; Hapich *et al*., 2023). Unfounded regimes of chernozem soils irrigation lead to negative processes associated with excessive accumulation of harmful salts in the upper layer of the soil, acidification, raising the level of groundwater, over-compaction, etc. These processes encourage further research into the agromelioration state of irrigated soils when irrigated with water that is limited in use (Rudakov & Hapich, 2019).

The effect of chemical ameliorants is to squeeze out, or create an obstacle for the entry of sodium into the soil absorption complex, due to which the physical properties of the soil change in the direction of a favorable regime for increasing the productivity of agricultural crops. Due to the displacement of the soil absorption complex of sodium by calcium or other two- or three-charged cations, the mobility of soil colloids decreases, the content of nutrients (N, P, K) increases, alkalinity decreases, and microbiological processes in the soil are activated (Syed *et al*., 2021).

According to the results of scientific research conducted in the conditions of the Northern Steppe of Ukraine, the peculiarities of the degradation processes occurring in irrigated soils were established, which are determined by the quality of irrigation water, initial physical properties of soils, anti-saline buffering capacity, depth of occurrence and mineralization of groundwater (Makarova *et al*., 2020).

Analyzing modern scientific publications, we can conclude that in order to save resources and increase efficiency, chemical land reclamation should be based on new conceptual provisions, namely: in the first place, soils with a medium and strong degree of salinity are subject to land reclamation; it is necessary to introduce ameliorants into the soil in the form of a solution or suspension, as well as locally along the contours of saline soils in periods of maximum salinity; application in a complex of hydrotechnical, chemical and agrotechnical land reclamation on irrigated soils (Cuevas *et al*., 2019; Syed *et al*., 2021).

The object of research are soils irrigated for 50 years, and the processes of changing their fertility indicators depending on the dose of phosphogypsum application.

The subject of research is the change in the chemical composition of the water extraction of irrigationally saline soils when using phosphogypsum as a chemical ameliorant.

The purpose of the research was an ecological improvement assessment of the state of irrigated soils, as well as the improvement of existing measures to reproduce the fertility of salinized irrigated soils by applying different doses of phosphogypsum. To accomplish the intended objective, several tasks need to be addressed, including: 1) scrutinizing the global and Ukrainian practices of utilizing phosphogypsum to ameliorate saline and salinized soils; 2) conducting a sequence of experiments under varying doses, durations, and conditions of implementing the ameliorant; 3) substantiating the ideal technological guidelines for employing phosphogypsum to deter soil degradation processes in areas irrigated with mineralized waters.

MATERIALS AND METHODS

To solve the main tasks proposed in this scientific work, the methods used in existing research were analyzed through a systematic approach to solving the problem of improving the ecological condition of irrigated lands. Methods of analysis and synthesis were used to establish the optimal method of combating soil salinization; conducted experimental studies in field and laboratory conditions. Field experiments were conducted to study the effect of chemical reclamation on the physical properties of the soil, and laboratory experiments were conducted to determine the physical and chemical properties of the soil and meliorants. Statistical methods were used to assess the reliability of the obtained research results. All research was conducted in compliance with current ethical and environmental standards (Law of Ukraine No. 962-IV, 2003; Thompson, 2017).

The research was provided in 2010-2021 near the village of Oleksandrivka on the territory of the Experimental Farm of the Dnipro Experimental Station of the Institute of Vegetable and Melon Growing of the National Academy of Agrarian Sciences of Ukraine, in the Dnipro district of the Dnipropetrovsk region. The experimental fields of this farm are located near a lake on the Samara River, and field experiments were conducted on an area of 60 hectares, which is shown in Figure 1.

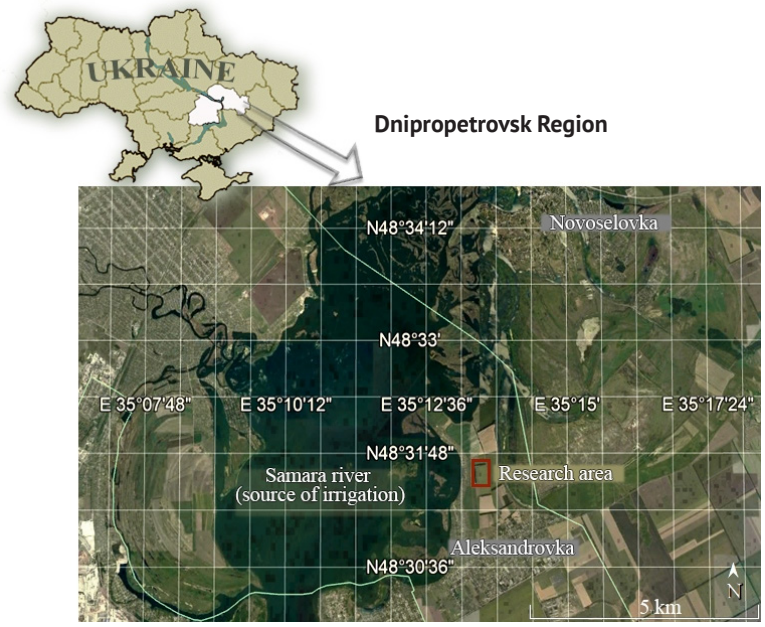

***Figure 1**. The place of research*
***Source:** developed by the authors based on data from the Google Earth Pro service*

The experimental plots are represented by ordinary chernozem, and the parent rock is loam loess, as evidenced by agrochemical and physical-mechanical indicators. The soils are classified as low-humus, as the content of the organic part reaches 2.5% (in the arable layer of the soil), and at a depth of 105 cm, its content is only 0.3%.

The hydrogen index of the soil in the experimental areas is in the range of 6-7.5. The total amount of toxic salts is 0.35-0.48%. In the soil absorption complex, the percentage content of exchangeable sodium is 3.64% with an absorption capacity of 23.29 meq per 100 g of soil. The salt composition of the soil and the content of the soil-absorbing complex indicate the development of salinization processes with a medium degree of salinity. According to N.A. Kachynskyi (Kovda, 1979) the granulometric composition of the soil belongs to light loam, since the arable layer contains 72.51% of physical sand, and 27.49% of physical clay. The mineralization of groundwater reaches 15 g/l with a depth of up to 5 m.

These soils on the experimental site were watered for 50 years with mineralized water (more than 2 g/l) from the Samara River. During vegetation watering with mineralized water, the soil swells, becomes plastic, viscous, sticky and peptized. With this unsatisfactory physical and chemical condition, the drying soil quickly compacts and becomes impermeable.

Unsatisfactory physical and mechanical condition of the soils in the experimental areas is a cause for concern, so it became necessary to study it. many years of field experiments to choose ways to improve and eliminate salinization have been established. It was also planned to monitor the physical and mechanical indicators and the chemical composition of the water extract of the soil, to control the quality of irrigation during the period of observation.

Climatic conditions during the years of research were characterized by a hydrothermal coefficient of 0.95-3.52. With regard to weather conditions, precipitation fell extremely unevenly, mainly in the hot season and had a rather intense nature, which created a small supply of moisture for the growth and development of agricultural crops. The extreme change in air temperature during the years of research also did not increase the reserves of available moisture in the soil. Irtek sprinkler hose-drum machine was used for watering.

To improve the quality of ordinary salted chernozem, a calcium-containing ameliorant from a by-product of the mineral fertilizers production (phosphogypsum) was chosen.

The research scheme is shown in Table 1. According to the proposed recommendations, phosphogypsum was applied as a reserve for 3 years with and without irrigation.

***Table 1**. The field research scheme*

Conditions for providing moisture	Norm/methodology for calculating the application of phosphogypsum	Variant
Without irrigation	without adding phosphogypsum (control)	V1
	introduction of phosphogypsum under cultivation in the spring at the rate of 1.4 t/ha / Pfeffer's method as modified by Molodtsov, Ignatova, 1990	V3

Table 1, Continued

Conditions for providing moisture	Norm/methodology for calculating the application of phosphogypsum	Variant
Without irrigation	introduction of phosphogypsum under cultivation in the spring at the rate of 3 t/ha / O.M. Grinchenko method, 1980	V4
	introduction of phosphogypsum in the fall under the main tillage at the rate of 6 t/ha / the method of B.I. Laktionov, 1963	V5
	without adding phosphogypsum (control)	V2
With irrigation	introduction of phosphogypsum under cultivation in the spring at the rate of 1.4 t/ha / Pfeffer's method as modified by Molodtsov, Ignatova, 1990	V6
	introduction of phosphogypsum under cultivation in the spring at the rate of 3 t/ha / O.M. Grinchenko method, 1980	V7
	introduction of phosphogypsum in the fall under the main tillage at the rate of 6 t/ha / the method of B.I. Laktionov, 1963	V8

Source: *developed by authors based on O.V. Morozov et al. (2008)*

The established norms were determined according to the methods of calculation of ameliorative, agronomic and ecologically safe doses of phosphogypsum application. None of the calculated doses exceeded 10 t/ha, which is environmentally safe for this locally produced phosphogypsum.

The chemical composition of the aqueous extract of the soil (anion-cation content) characterizes its salinity type. To establish the chemistry of salinization, preference was given to negatively charged particles of the arable layer of the soil (30 cm) (Instruction of the State..., 2002).

All analyses were carried out in certified laboratories in Dnipro in accordance with the regulatory and methodological base in force in Ukraine (DSTU ISO 10390:2022, 2022; DSTU ISO 11260-2001, 2003; DSTU ISO 8466-1-2001, 2003; DSTU 7912:2015, 2016).

RESULTS AND DISCUSSION

Dnipropetrovsk region is characterized by a high percentage of arable land in agricultural land. Modern climatic features encourage the use of irrigation as the main intensifier of production. This causes uncontrolled irrigation both in terms of norms and quality of irrigation water. Previous experiments proved that watering with water suitable for irrigation can also have a negative effect on the physical, mechanical and other properties of soils (Makarova *et al.*, 2020). As for water that is limited for irrigation, its influence on the salt and exchange composition of the soil is much stronger compared to irrigation with fresh water. As a result of long-term irrigation with water of different quality in the territory of the Northern Steppe of Ukraine, an acute problem of secondary salinization and salting of lands arose. A change in the natural state leads to the degradation of soils, their removal from their intended purpose due to the loss of fertility (Onopriienko *et al.*, 2019).

As a result of the investigations, the anionic-cationic composition of the aqueous extract of the arable layer of the soil was determined in all experimental areas. The results of the average indicators of water extract analyzes for soil anions and cations in mEq/100 g of soil in the experimental areas are shown in Table 2.

Table 2*. Indicators of soil water extraction in the first three years of research*

Research variant	A year after the effect of phosphogypsum	Hydrogen index	Anionic composition, meq/100 g of soil			Cation composition, meq/100 g of soil			Sodium-adsorption ratio
			hydrocarbons	chlorides	sulfates	calcium	magnesium	sodium	
V1	first	7.4	0.324	0.99	2.306	0.621	0.58	2.42	3.12
	second	7.2	0.59	0.7	2.507	0.597	0.49	2.71	3.68
	third	7.4	0.348	0.897	2.421	0.573	0.47	2.623	3.63
V2	first	7.5	0.22	1.215	2.990	0.253	0.156	4.016	8.87
	second	7.4	0.575	1.248	2.75	0.313	0.278	3.982	7.33
	third	7.5	0.34	1.27	2.65	0.32	0.284	3.656	6.65
V3	first	7.17	0.169	1.158	3.17	0.73	0.363	3.404	4.61
	second	6.7	0.546	0.987	2.788	0.7	0.424	3.197	4.26
	third	7.2	0.28	1.198	2.694	0.678	0.395	3.104	4.24

Table 2, Continued

Research variant	A year after the effect of phosphogypsum	Hydrogen index	Anionic composition, meq/100 g of soil			Cation composition, meq/100 g of soil			Sodium-adsorption ratio
			hydrocarbons	chlorides	sulfates	calcium	magnesium	sodium	
V4	first	7.29	0.297	1.095	3.299	1.024	0.628	3.039	3.34
	second	6.89	0.486	1.0	2.8	1.0	0.395	2.891	3.46
	third	7.26	0.273	1.098	2.776	0.987	0.401	2.76	3.31
V5	first	7.37	0.289	1.122	3.325	1.56	0.687	2.488	2.35
	second	6.97	0.256	0.879	3.0	1.478	0.364	2.292	2.39
	third	7.34	0.258	0.898	2.845	1.425	0.389	2.188	2.30
V6	first	7.22	0.318	0.982	2.742	1.124	0.520	2.398	2.64
	second	6.75	0.48	0.627	2.7	1.1	0.45	2.257	2.56
	third	7.21	0.315	0.85	2.521	1.092	0.366	2.228	2.61
V7	first	7.36	0.37	0.898	3.038	1.579	0.427	2.3	2.30
	second	6.91	0.434	0.621	3.019	1.52	0.465	2.089	2.10
	third	7.3	0.291	0.856	2.764	1.489	0.42	2.002	2.05
V8	first	7.43	0.369	0.876	3.424	2.157	0.267	2.246	2.04
	second	7.0	0.567	0.612	3.366	2.1	0.477	1.968	1.73
	third	7.38	0.249	0.797	3.175	2.0	0.439	1.782	1.61

Source: *developed by authors*

On the control option where irrigation was carried out (V2), a tendency to decrease SO_4^{-2} ion indicators was observed, which is explained by the leaching of sulfates together with irrigation water. On the contrary, an increase in sulfates by 0.20 mEq/100 g of soil in the second year, compared to the first, and a further decrease in their amount in the third year were seen on the control plots without irrigation. The second year of research was characterized by increased air temperature compared to the average long-term values, which, as it is supposed, caused the arrival of sulfates from the lower layers of the soil profile during this period of research.

The anionic indicators of the aqueous extraction of the soil (Table 2) were marked by an increase in the amount of SO_4^{-2} compared to the control option where irrigation was not carried out and phosphogypsum was not applied during the entire period of research. The average annual amount of SO_4^{-2} ions in the irrigated options during the observation period increased by 15-18% compared to the non-irrigated control options of the experiments.

This fact can be explained by the ingress of SO_4^{-2} ions into the arable layer of the soil together with irrigation water. This is confirmed by the results of the observations, since the number of SO_4^{-2} ions was significantly lower in the control variants in the absence of irrigation. The exception was the second year of observations, in which the amount of sulfates was the highest – 2.51 meq/100 g of soil.

The maximum concentration of SO_4^{-2} (V8, Table 2) was obtained in the irrigated areas with the introduction of the largest dose of phosphogypsum compared to the control areas without irrigation with the use of phosphogypsum. According to the data in this table, the average annual indicators of SO_4^{-2} concentration are 3.18-3.43 mEq/100 g of soil, which is 0.87-0.92 mEq/100 g of soil more than the control options without irrigation. Application of phosphogypsum in different doses on irrigated areas (V6, V7, V8) led to the accumulation of SO_4^{-2} ions in proportion to the increase in the dose of its application. Analyzing the changes in the number of sulfate ions in these variants of the experiments, according to the years of research, a pattern of decreasing SO_4^{-2} ions was observed to 2.5 meq/100 g of soil (V6), to 2.8 meq/100 g of soil (V7) and to 3.2 meq/100 g of soil (V8) in the third year (Table 2).

A tendency to increase the content of sulfate ions was observed in variants with phosphogypsum when irrigated compared to the non-irrigated control. Comparing the two control options (with and without irrigation) and options with phosphogypsum application during irrigation, an increase in average annual SO_4^{-2} ions by 0.42 meq/100 g of soil was observed. In areas where phosphogypsum was applied without irrigation, the content of SO_4^{-2} ions increased when the dose of phosphogypsum application was increased. At a dose of phosphogypsum application of 1.4 t/ha, there were 3.17 meq/100 g of soil sulfate, while at a dose of 6 t/ha – 3.33 meq/100 g of soil in the first year after the action. During the years of the meliorative effect, the amount of sulfate ion gradually decreased by an average of 15% in the third year after the effect. Compared

to the control irrigated options, the content of SO_4^{-2} ions increased by only 0.42 meq/100 g of soil with the introduction of a dose of phosphogypsum of 6 t/ha during irrigation, while at lower doses such a trend was not observed. For doses of phosphogypsum application of 6 t/ha during irrigation in the third year, the content of sulfate ions also increased by 0.53 meq/100 g of soil compared to the control plots. This is explained by the arrival of SO_4^{-2} ions with mineralized irrigation water and their content in phosphogypsum. The gradual decrease in the number of ions in the third year after the application of phosphogypsum is explained by the removal of the formed sodium sulfate into the lower soil horizons (Onopriienko *et al.*, 2019)

During the research period, no corresponding dependence was observed in the change in the amount of HCO_3^{-1}. An insignificant decrease in the content of hydrocarbons was noted in the areas where irrigation was carried out and different amounts of phosphogypsum were applied. The absence of watering and phosphogypsum in the experimental areas led to an increase in the content of HCO_3^{-1} ions.

In the areas where irrigation was carried out and phosphogypsum was applied in relation to the control irrigated areas, the content of HCO_3^{-1} ions differed by 0.04-0.06 meq/100 g of soil according to the average annual values. On the control plots without irrigation, up to 0.07 meq/100 g of soil more hydrocarbons were noted in comparison with variants V3, V4 and V5 where phosphogypsum was applied, but without irrigation.

The content of HCO_3^{-1} ions in the water extract of the soil did not show a clear dependence on the dose of phosphogypsum application. In the areas where irrigation was carried out and without irrigation, the highest concentration of hydrocarbons was obtained at a dose of phosphogypsum application of 3 t/ha. The highest value of this ion content was recorded in the second year after the action in the options where irrigation was carried out (V6) – 0.567 meq/100 g of soil, as well as in the areas without irrigation (V3) – 0.55 meq/100 g of soil.

During the research, the dependence of irrigation on the increase in the concentration of Cl ions in the soil was established. In the experiments, chlorides entered the soil only during irrigation with mineralized water. The content of Cl ions increased by one and a half times when irrigated with water from the Samara River compared to non-irrigated control variants. Application of phosphogypsum and irrigation compared to the control options without irrigation reduced the chloride content in the soil by 34%. The lack of irrigation due to the introduction of phosphogypsum did not affect the change in the concentration of chlorine ions. In the control plots during the research years, this indicator was 0.86 meq/100 g of soil. When applying phosphogypsum at a dose of 1.4 t/ha, the content of chlorine ions was 1.11 meq/100 g of soil, and at doses of 3 and 6 t/ha – 1.0 meq/100 g of soil.

The amount of chlorine ions did not depend on the dose of phosphogypsum during the entire period of research. In the absence of irrigation after the application of phosphogypsum, the lowest indicators of chloride content were noted in the second year after the action at a dose of phosphogypsum application of 6 t/ha, which is 10% lower than the application dose of 1.4 t/ha. This tendency was also preserved in the irrigated areas with the introduction of phosphogypsum, only with a decrease in the total content of chlorides by 35-48% compared to the control irrigated options. This regularity is explained by the redistribution of chlorine anions to sulfate ions.

The type of soil salinity was determined by the ratios of the maximum values of the content of anions-cations, the results of which are shown in the Table 3. According to the chemical composition of the anionic component of the water extract of the soil from the experimental plots, the sulfate type of salinization was established in variants with phosphogypsum on irrigated and non-irrigated plots. In the control variant (V1), the soda-sulfate type was installed only in the first year of observations. In the future, on this variant, self-improvement of non-irrigated soil changed the chemistry to sulfate. By combining anions and cations into hypothetical molecules of the appropriate amount (meq/100 g of soil), the degree of salinity equivalent to chlorine and the amount of toxic salts in percent were determined for all variants of experiments.

Table 3. *Type and degree of soil salinization*

Research variant	Degree of salinity/chemism (type) of salinity	A year of research		
		first	second	third
V1	The degree of salinity is equivalent to Cl, meq	0.61	1.39	0.76
	$S_{tox.\ salts}$, %	0.21	0.32	0.29
	Chimism (type)	sodium sulfate	sodium sulfate	sodium sulfate
V2	The degree of salinity is equivalent to Cl, meq	1.39	1.69	1.99
	$S_{tox.\ salts}$, %	0.3	0.35	0.36
	Chimism (type)	sodium sulfate	sodium sulfate	sodium sulfate

Table 3, Continued

Research variant	Degree of salinity/chemism (type) of salinity	A year of research		
		first	second	third
V3	The degree of salinity is equivalent to Cl, meq	1.39	1.49	1.63
	$S_{tox.\ salts}$, %	0.37	0.38	0.35
	Chimism (type)	sodium sulfate	sodium sulfate	sodium sulfate
V4	The degree of salinity is equivalent to Cl, meq	1.39	1.52	1.96
	$S_{tox.\ salts}$, %	0.39	0.39	0.37
	Chimism (type)	sodium sulfate	sodium sulfate	sodium sulfate
V5	The degree of salinity is equivalent to Cl, meq	1.7	1.62	1.88
	$S_{tox.\ salts}$, %	0.4	0.38	0.38
	Chimism (type)	sodium sulfate	sodium sulfate	sodium sulfate
V6	The degree of salinity is equivalent to Cl, meq	1.6	1.51	1.75
	$S_{tox.\ salts}$, %	0.58	0.41	0.4
	Chimism (type)	sodium sulfate	sodium sulfate	sodium sulfate
V7	The degree of salinity is equivalent to Cl, meq	1.5	1.41	1.56
	$S_{tox.\ salts}$, %	0.42	0.41	0.4
	Chimism (type)	sodium sulfate	sodium sulfate	sodium sulfate
V8	The degree of salinity is equivalent to Cl, meq	1.5	1.48	1.48
	$S_{tox.\ salts}$, %	0.41	0.41	0.41
	Chimism (type)	sodium sulfate	sodium sulfate	sodium sulfate

Source: *developed by authors*

According to FAO standards (1988), the degree of soil salinization depends on the sodium-adsorption ratio (SAR). In a particular case, based on the received cation indicators, SAR values were obtained in the first three years of research, the values of which are shown in Figure 2.

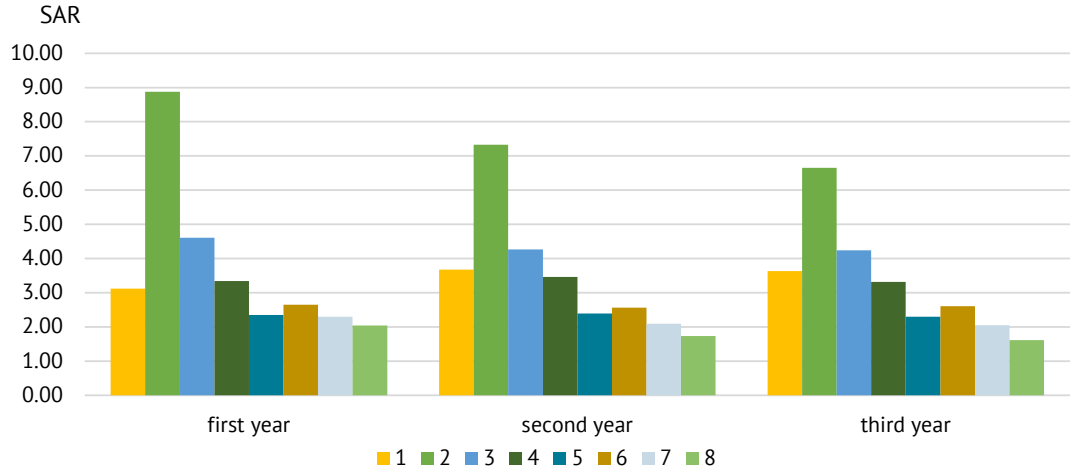

Figure 2. *Indicators of the SAR according to research options in the years of research*
Source: *developed by authors*

It was established that the degree of soil salinity depends on the values of the pH and SAR indicators, and for all variants of research it is characterized as slightly saline, and for the first variant of experiments (V1) salinity is characterized by an average degree. Analyzing the indicators of the control plots in the variant without irrigation, an increase in the SAR indicator by 0.56 units was observed in the second year. This trend also occurred with SO_4^{-2} ions. This indicates the influx of sodium sulfate from the lower layers of the soil profile into the arable layer during this period.

The change in the SAR indicator in the third year after the effect of chemical reclamation at a depth of 0-105 cm (Fig. 2) is characterized by minimal indicators.

The effective indicators of SAR reduction correspond to options where mineralized water was irrigated and phosphogypsum was applied at doses of 3 and 6 t/ha, as well as without irrigation, where phosphogypsum was applied at the recommended dose of 6 t/ha.

The restructuring of the water management sector, particularly in agricultural irrigation reclamation, has resulted in reduced funding and the cessation of reclamation science development. This is exemplified by a substantial decline in scholarly works on the topics of reclamation soil science and the effects of irrigation water quality on soils, despite the necessity of these studies being undisputed among experts. The most recent fundamental research conducted in Ukraine regarding these concerns is a decade or more old, and the quality of both irrigation water and water resources in general continues to deteriorate, a trend that is also observable globally (Kuzminskyi & Natalchuk, 2004).

The research conducted by R.O. Babushkina (2006) reports the outcomes of a study examining the impact of chemical land reclamation (limestone applied at rates of 5, 10, and 15 t/ha and phosphogypsum applied at rates of 12, 24, and 36 t/ha) and irrigation on the primary physical and physicochemical properties of black soil that is typically found in the irrigated regions of southern Ukraine. O. Nosonenko *et al*. (2022) have established the patterns of the effect of various doses of gypsum on the physicochemical and saline indicators of slightly saline dark-chestnut soil in the Kherson region. In contrast to the above-mentioned soil types, which are dark-chestnut and southern chernozems, research has focused less on the effectiveness and techniques of calcium ameliorant application on ordinary chernozems. Questions pertaining to the feasibility and efficacy of using gypsum on chernozems with mild degrees of salinization are still debatable, and there is a lack of defined approaches for calculating ameliorant dosages, insufficiently clarified quantitative indicators for the interaction between gypsum, soil, and irrigation water, and poorly developed ecological aspects of using chemical ameliorants. The issues surrounding the chemical reclamation of irrigated chernozems, which are frequently affected by salinization due to the use of Class I and II waters for irrigation, and their subsequent degradation (e.g. compaction, destructuring, and crust formation), remain unresolved.

All anions and cations contained in the water extract of the soil are bound into the corresponding chemical compounds. Some obtained compounds have a negative effect on the growth of plants and their physiological state. Such chemicals include compounds of carbonates and chlorides. Chlorides slow down plant growth and are toxic substances for most agricultural crops, for example, for corn (Cui *et al*., 2019). Na_2SO_4 ions can also be a restraining factor in the development of some plants, but this substance dissolves very well in water and contains sulfur, which takes part in redox reactions, the creation of protein molecules, energy exchange and is a building material for plant cells (Peng *et al*., 2008).

Therefore, one of the elements that should be incorporated into the revitalization (restoration) system of hydrotechnical reclamation is the study of issues related to the improvement of the ecological and reclamation state of soils and its impact on the production of high-quality agricultural products.

CONCLUSIONS

Studies have shown that the introduction of phosphogypsum as a chemical ameliorant on irrigated saline chernozems improves the anion-cation composition of water extract and the degree of soil salinity. In all versions of the experiments, according to the cationic composition of the aqueous extract of the soil, the sodium type of salinization was established. Remedial measures by applying phosphogypsum under irrigation conditions change the anionic composition of the soil aqueous extract in the direction of increasing sulfate ions, which characterizes the sulfate chemistry of the soil. In the absence of irrigation and without the introduction of phosphogypsum, the soils had a soda-sulfate type of salinity.

The reaction of the soil solution during the years of observation was close to neutral (6.7-7.9). The degree of soil salinity in the experimental areas was determined by the "total effect" of hypothetically bound toxic ions. The variants of experiments with the application of phosphogypsum at the rate of 3 and 6 t/ha during irrigation, where the degree of salinity changed from medium to slightly saline, responded best. The SAR in the third year after the application of phosphogypsum in relation to the control parameters without irrigation decreased by 10%. Application of phosphogypsum and irrigation of vegetation in the third year after the effect led to the best results, that is, there was a decrease in SAR indicators in relation to the control variants by 69%. This confirms the theory of increased ameliorative effect of phosphogypsum under irrigation conditions.

Based on the SAR value, the degree of salinity of the experimental plots was characterized as a weakly saline type in the variants with phosphogypsum application, and moderately saline in the control variant with irrigation. According to the SAR indicators, the best options for irrigation with water of the II quality class were the doses of phosphogypsum for cultivation in the spring – 3 t/ha and in the fall for the main tillage – 6 t/ha.

Future scientific research should be based on a comprehensive approach to solving optimization problems related to chemical melioration of irrigation water, introducing calcium meliorants into the soil as a solution or suspension, local application along the

contours of saline soils during periods of maximum physical salinity manifestation, resource and energy conservation, deep meliorative tillage on irrigated soils, and cultivation of moisture-loving, high-yielding, and saline-resistant crops.

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CONFLICT OF INTEREST

None.

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Запобігання процесам деградації зрошуваних мінералізованими водами ґрунтів шляхом гіпсування

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Анотація. Тривале зрошення значних площ степової зони України неякісною та мінералізованою водою призвели до деградаційних процесів, пов'язаних із засоленням та осолонцюванням ґрунтів. Для обмеження або послаблення цих процесів досліджено можливість застосовування хімічної меліорації шляхом внесення фосфогіпсу. Дослідження проведені в умовах північного Степу України на дослідних ділянках, розташованих біля села Олександрівка Дніпровського району Дніпропетровської області. Були закладені багаторічні польові досліди з внесенням фосфогіпсу як хімічного меліоранту. Схема дослідів передбачала внесення фосфогіпсу у різні періоди року меліоративними нормами 1.4, 3.0 та 6.0 т/га. Відбір проб, лабораторні аналізи та опрацювання отриманих результатів виконано із застосуванням стандартизованих методів досліджень. На ділянках досліджень встановлено високий вміст солей в орному шарі ґрунту (0.35-0.48 %), ознаки осолонцювання (вміст обмінного натрію 3.64 %) та незадовільний фізичний стан ґрунту. Внесення фосфогіпсу привело до збільшення аніонів сульфату, що відображалося на сульфатному хімізмі ґрунту, а на контрольних ділянках зберігався содово-сульфатний тип засолення. Встановлено, що рівень pH водної витяжки за роки досліджень знаходився в межах нейтральних значень. Позитивні зміни спостерігали при визначенні ступеня засолення ґрунту, а саме при внесенні фосфогіпсу нормами 3 та 6 т/га на поливних ділянках ступінь засолення змінювався з середнього до слабко засоленого. За результатами зменшення натрієво-адсорбційного відношення доведено позитивну дію внесення фосфогіпсу при зрошенні на третій рік післядії. Відмічається краща меліоративна дія фосфогіпсу при поливах за рахунок зменшення показника натрієво-адсорбційного відношення щодо контрольних варіантів на 69 %. За умов поливу водою II класу якості найкращим варіантом внесення фосфогіпсу є дози 3 т/га під культивацію навесні та 6 т/га під основний обробіток восени. Це забезпечує зниження ступеня засолення ґрунтів та дозволяє покращити еколого-меліоративний стан території при зрошенні

Ключові слова: меліорація земель; зрошення; осолонцювання; фосфогіпс; натрієво-адсорбційне відношення; ступінь засолення

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Herbicide influence on the agrocenose of soy and its photosynthetic activity in the western Forest Steppe of Ukraine

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Abstract. The use of herbicides can significantly affect the processes of plant photosynthesis, as it leads to inhibition of pigment production, impairs the transport of electrons in the respiratory chain and carbon fixation. The purpose of the study is to determine the effect of herbicide application on weediness and photosynthetic activity of soybeans. On the basis of a field study in the conditions of the Educational and Scientific Center of the Lviv National University of Nature Management, the dependence of soybean yield on the level of weediness of the culture was established. The highest yield of soybeans – 29.0 t/ha was obtained in the application of the herbicide Primekstra TZ Gold 500 SC c.s. (4.5 l/ha), the smallest – 27.3 t/ha among the experimental variants was obtained with the post-emergence application of the herbicide Pulsar s.c. (1 l/ha). Application of herbicide Primekstra TZ Gold 500 SC c.s. did not affect the intensity of photosynthesis, and the number of pigments in soybean leaves was not significantly different from the indicator in the control. The use of drugs Kommand k.e. and Pulsar s.c. led to a slight decrease in the number of pigments in the first days after application and their gradual stabilization. Use of the herbicide Concur c.s. had the effect of weakening photosynthetic activity and reducing the number of pigments. This indicates that the active substance metribuzin is not absolutely selective with regard to the effect on soybean plants, that is, in the case of its use, there is a probability of suppressing the culture. The practical significance of the obtained results lies in revealing the possibilities for choosing effective herbicides with increased selective phytotoxicity, which provide effective control of the number of weeds with a minimal probability of a negative impact of herbicides on the soybean agrocenosis

Keywords: soybean; pigments; active substance; photosynthesis; weeds; productivity

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INTRODUCTION

Photosynthesis is an important process for plant life, as it provides the synthesis of organic compounds necessary for plant growth and development. Herbicides can have a significant negative impact on the photosynthetic activity of plants and lead to a decrease in yield, deterioration of product quality, and threaten the ecosystem. The application of herbicides can have different effects on the photosynthetic activity of plants, since these agents are designed to control weeds and other unwanted plants, and not to directly affect crops. Depending on the used herbicide, dose, time of application and environmental conditions, the effect may be different.

Herbicides that affect the synthesis of amino acids or proteins can reduce the level of photosynthetic pigments and limit the ability of plants to photosynthesize. They can cause oxidative stress in the plant, which can cause cell damage and reduce photosynthetic activity (Nosek *et al.*, 2017; Han *et al.*, 2022).

One of the key reactions of photosynthesis is photochemical electron transport, which is carried out by photosystem complexes centered on chloroplast membranes, herbicides can inhibit the processes of photosynthesis by delaying this electron transport (Gamayunova & Panfilova 2019).

Research by A.T. Taylor & E.P.C. Lai (2021) stablished that, when entering the plant, the active substance glyphosate inhibits the production of the EPSP synthetase enzyme. Inhibition of the activity of this enzyme blocks the formation of aromatic amino acids by plants, important for their growth and components of many plant pigments, the structure and activity of chloroplasts is reflected in the reduced amount or absence of photosynthetic pigments.

However, there is an assortment of herbicides that do not have a negative effect on the photosynthetic activity of plants or can even enhance it. In particular, herbicides that reduce competition with weeds can help plants increase the availability of light, water and nutrients and make them more efficient at photosynthesis (Gomes *et al.*, 2014).

G.B.P. Braz *et al.* (2022) show that herbicides can affect the photosynthetic activity of soybeans by slowing photosynthetic electron transport. Such a process can lead to a weakening of the photosynthesis process and, accordingly, to a decrease in the production of organic substances necessary for plant growth and development. Herbicides can also affect the development of chloroplasts and other cell organelles that affect photosynthetic activity.

Research by J. Constantin *et al.* (2020) established that the introduction of herbicides can reduce the photosynthetic activity of soybeans, in particular, due to a decrease in the amount of chlorophyll in the leaves and an increase in the concentration of reagents that cause oxidative stress in the plant. However, as S. McCown *et al.* (2018) point out, the effect of herbicides on photosynthetic activity may be small or even absent, depending on the specific herbicide and soybean growing conditions.

The purpose of the research was to determine the herbicidal effect on soybean agrocenosis and its photosynthetic activity. To achieve the set goal, the following tasks were completed:

1. The effectiveness of weed control in soybean crops depending on the use of herbicide was investigated.

2. The influence of herbicides on the yield of soybean seeds was established.

3. The effect of herbicides on the pigment content and photosynthetic activity of soybeans was investigated.

MATERIALS AND METHODS

Research on the effectiveness of herbicides on weediness and photosynthetic activity of soybeans was carried out during 2021-2022 in the conditions of the educational and scientific center of the Lviv National Environmental University.

For the study, the precocious soybean variety Ustya was used (originator – NSC "Institute of Agriculture of the National Academy of Sciences of Ukraine"). Soybeans were sown in the usual row method with a row width of 15 cm, with a sowing rate of 650,000 similar seeds per hectare at a soil temperature of 10-12°C at the depth of seed wrapping. The soybean fertilization system included application of 140 kg/ha of ammonium nitrate and 100 kg/ha of ammonium sulfate.

The soybean protection system against weeds involved the application of herbicides with different mechanisms of action, namely: the soil herbicide Primekstra TZ Gold 500 SC (active substance – Metolachlor, Terbuthylazine) before the appearance of seedlings of cultivated plants and post-emergence – in phase 1-3 trifoliate leaves in crops: Kommand (active substance – Clomazone), Pulsar (active substance – Imazamox), Concur (active substance – Metribuzin).

The experiment included four options with 3 repetitions: Variant 1 – control (without application of herbicides); Variant 2 – Primekstra TZ Gold 500 SC c.s. (4.5 l/ha); Variant 3 – Kommand k.e. (0.2 l/ha ha); Variant 4 – Pulsar s.c. (1 l/ha); Variant 5 – Concur c.s. (0.7 l/t). The area on which the experiment was laid is 0.5 ha with randomized placement of plots, the distance between them is 0.4 m.

The level of weediness was measured using a quantitative method with overlapping frames with an area of 0.25 m^2 in four places diagonally. The species diversity of weeds was determined in the seedling phase, flowering and at the time of soybean harvest. The obtained results were compared to the control (variant without

herbicide application). The actual weediness of crops was evaluated in points according to the visual-quantitative method of A.G. Maltsev. At the same time, the weediness score was determined both for all types of weeds in general and for their individual types.

The photosynthetic activity of soybeans was determined by CO_2 (carbon dioxide) gas exchange, which was measured using an infrared optical-acoustic gas analyzer. The content of photosynthetic pigments was determined by the method of extracting a portion of plant material in a water bath at a temperature of 67°C for 3 hours (Pradhan *et al.*, 2018). The content of pigments was calculated in μg/mg mass of raw material.

Soybean productivity was calculated by continuous manual harvesting with preliminary mowing of the above-ground mass of plants. Processing of the obtained research results for reliability was carried out using the multivariate MANOVA method of variance analysis using Microsoft Excel software and the Statistica 10 program package. Differences in the obtained results are possible at the level of significance $P \leq 0.05$ according to the Student's test.

The research was conducted in accordance with ethical requirements. Experimental plant studies, including collection of plant material, followed institutional and international guidelines. The research also adhered to the standards of the Convention on Biological Diversity (2022).

RESULTS

During the years of research, it was established that the agrocenosis of soybeans was dominated by one-year weed species, namely: *Setaria glauca* L., *Chenopodium album* L., *Echinochloa crus-galli* L., *Amaranthus retroflexus* L., *Raphanus raphanistrum* L. etc. Of the perennial weed species were *Sonchus arvensis* L., *Equisetum arvense*, *Elytrigia repens*, *Convolvulus arvensis* (Fig. 1).

The share of annual weed species in general was 53-68% of all species, in particular: *Chenopodium album* occupied 10% in the structure of annual weeds, *Convolvulus arvensis* – 12%, *Amaranthus retroflexus* L. – 19%, *Galinsoga parviflora* Cav. – 10%, *Polygonum convolvulus* L. – 13%. About 9-11% were perennial rhizome weeds, in particular *Equisetum arvense* L. and *Elymus repens*.

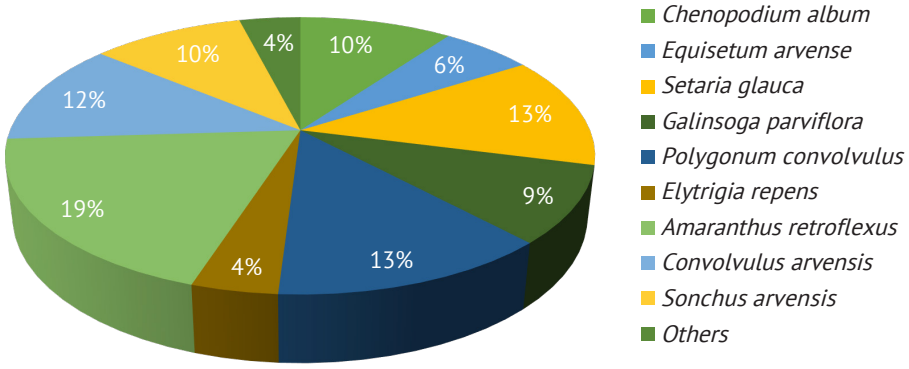

Figure 1. *Main types of weeds in soybean crops, % (average for 2021-2022)*
Source: *developed by authors*

Root weeds accounted for 17-22%, among them were *Sonchus oleraceus, Convolvulus arvensis* L., and dandelion *Taraxacum officinale*.

Over the years of the study, during the growing season of soybeans, records of the dynamics of weediness of crops were made, which made it possible to determine the structure of weediness and to apply herbicides in time and prevent the development of weeds. In the option of using the pre-emergence herbicide Primekstra TZ Gold 500 SC c.s. in the seedling phase of soybeans, there were, on average, the fewest weeds (7 pcs./m^2). This is due to the introduction of post-emergence herbicides in the phase of 1-3 trifoliate leaves in soybeans (Table 1).

Table 1. *Dynamics of weediness of soybean crops, pcs./m^2 (average for 2021-2022)*

Variant	Weed accounting period		
	seedling phase	flowering phase	harvesting
Control (without application of herbicides)	23	62	113
Primekstra TZ Gold 500 SC c.s. (4.5 l/ha)	7	15	22
Kommand k.e. (0.2 l/ha ha)	16	19	24
Pulsar s.c. (1 l/ha)	19	22	26
Concur c.s. (0.7 l/t)	18	20	24

Source: *developed by authors*

At the time of harvesting soybeans, the least weeded on average over the years of the study (22 pcs./m^2) were the crops in the variant of the experiment with the pre-emergence application of the herbicide Primekstra TZ Gold 500 SC c.s. at a rate of 4.5 l/ha, which is 80.5% less compared to the control (113 units/m^2). This introduction made it possible to effectively control grass and dicotyledonous weeds in soybean crops. For post-emergence application of Pulsar s.c. (1 l/ha) at the time of soybean harvest, among the variants of the experiment, the largest number of weeds was established – 26 pcs./m^2.

Observations of the dynamics of the appearance of weeds showed that most of them germinate in the period from the phase of soybean seedlings to budding, then the culture can compete with weeds and inhibit their development. In addition, the lowest indicator of weediness in the seedling phase of soybeans was established at 1-2 points in the variant of using the herbicide Primekstra TZ Gold 500 SC c.s. During this period, annual early spring and late spring types of weeds began to emerge. In the flowering phase of soybeans, in all variants of the experiment, weediness of the crops was 2-3 points. At the time of soybean harvest, weediness of the crops was the highest. The study of the effectiveness of herbicides in soybean crops of the Ustya variety established the effect not only on reducing the number of weeds, but also on increasing the yield of soybeans compared to the control (Table 2).

Table 2. *Effect of herbicides on soybean yield, c/ha*

Variant	Year		Average for 2021-2022	± to control, %
	2021	2022		
Control (without application of herbicides)	24.5	23.7	24.1	-
Primekstra TZ Gold 500 SC c.s. (4.5 l/ha)	28.7	29.3	29.0	+20.3
Kommand k.e. (0.2 l/ha ha)	27.1	28.6	27.9	+15.8
Pulsar s.c. (1 l/ha)	26.9	27.7	27.3	+13.3
Concur c.s. (0.7 l/t)	26.8	27.9	27.4	+13.7
LSD_{05}	1.24	1.32		

Source: *developed by authors*

The highest yield of soybean grain on average for 2021-2022 was obtained in the variant of using the herbicide Primekstra TZ Gold 500 SC c.s. (4.5 l/ha) – 29.0 t/ha, which is 20.3% higher than the control (24.5 t/ha). It was the smallest (27.3 c/ha) in the variant of post-emergence application of the herbicide Pulsar s.c. (1 l/ha). Thus, the yield of soybeans depends on the level of weediness of crops, and the use of herbicides can prevent not only crop yield losses, but also increase it.

The study of the effect of herbicides on the photosynthetic activity of soybeans showed that the introduction of the herbicide Primekstra TZ Gold 500 SC c.s. did not affect the decrease in the intensity of photosynthesis, and the number of pigments in soybean leaves was not significantly different from the control. However, in the case of the use of the drugs Kommand k.e. and Pulsar s.c. a slight decrease in the number of pigments in the period after the application of herbicides, which was accompanied by their stabilization, was established on average over the years of the study. And the introduction of the herbicide Concur c.s. led to a weakening of photosynthetic activity and a decrease in the number of pigments (Table 3; Table 4).

Therefore, the active substance metribuzin is not absolutely selective for soybeans, that is, in the case of its use, there is a probability of suppressing the culture.

Table 3. *Pigment content (μg/mg raw substance) in soybean leaves (average for 2021-2022)*

Variant	2021			2022		
	chlorophyll *a*	chlorophyll *в*	carotenoids	chlorophyll *a*	chlorophyll *в*	carotenoids
Control (without application of herbicides)	1.78	0.64	0.86	1.88	0.71	0.92
Primekstra TZ Gold 500 SC c.s. (4.5 l/ha)	1.69	0.74	0.95	1.92	0.83	0.86
Kommand k.e. (0.2 l/ha ha)	1.76	0.71	0.88	1.93	0.79	0.91
Pulsar s.c. (1 l/ha)	1.80	0.75	0.89	1.89	0.75	0.87
Concur c.s. (0.7 l/t)	1.56	0.35	0.54	1.63	0.39	0.61
LSD_{05}	1.19	1.08	1.31	1.36	1.29	1.46

Source: *developed by authors*

Table 4. *Photosynthetic activity of soybeans, mg CO_2/(dm^2×h)*

Variant	2021	2022	Average for 2021-2022
Control (without application of herbicides)	34	36	35
Primekstra TZ Gold 500 SC c.s. (4.5 l/ha)	35	38	36.5
Kommand k.e. (0.2 l/ha ha)	37	36	36.5
Pulsar s.c. (1 l/ha)	36	39	37.5
Concur c.s. (0.7 l/t)	31	29	30
LSD_{05}	1.26	1.64	1.43

Source: *developed by authors*

Application of soil herbicides prior to soybean and weed emergence increases the effectiveness of weed control, soybean yield, and herbicide selectivity relative to the crop.

DISCUSSION

Herbicides are widely used in agriculture to control weeds on agricultural and other lands. However, the research of A. Panfilova *et al.* (2019) proves that the use of herbicides can have a negative effect on the photosynthetic activity of plants. Herbicides can disrupt the natural process of photosynthesis by interfering with key processes such as electron transport, carbon fixation, and pigment production, which also correlates with the study.

The effect of herbicides on the photosynthetic activity of soybean depends on the type of herbicide and the application rate. Some active substances, such as glyphosate, suppress the production of certain amino acids important for protein synthesis, which leads to a weakening of plant growth and photosynthetic activity. Also, glyphosate can reduce the activity of the enzyme ribulose-1.5-bisphosphate carboxylase/oxygenase (Rubisco), which is necessary for carbon fixation in the process of photosynthesis. This can lead to reduced photosynthetic efficiency and reduced plant growth and yield (Korpita & Shuvar, 2020; Soares *et al.*, 2020) In addition, active substances such as atrazine and metribuzin have been shown to disrupt the electron transport chain in photosynthesis, leading to a decrease in energy production and photosynthetic activity (Corrêa & Alves, 2010; Shuvar *et al.*, 2022). Certain herbicides can disrupt the electron transport chain in photosynthesis, which can lead to reduced energy production and photosynthetic activity. For example, atrazine alters the electron transport chain, leading to reduced ATP (Adenosine triphosphate) production and ultimately reduced photosynthesis in plants (Banerjee *et al.*, 2022; Shuvar & Korpita, 2023).

According to the results of the research by S. Kaeoboon *et al.* (2021) and R. Cruz de Carvalho *et al.* (2022), the use of herbicides can affect the processes of CO_2 gas exchange in plants and the efficiency of photosynthesis. Studies have shown that the use of herbicides can reduce the stomatal conductance of plants, thereby limiting the supply of CO_2 to the leaves and accompanied by a decrease in growth and yield of agricultural crops and a weakening of photosynthetic activity, which is also reflected in the performed study. On the other hand, it was established that some herbicides have a positive effect on CO_2 gas exchange. For example, some systemic herbicides can increase the rate of CO_2 assimilation by leaves, which can lead to improved growth and increased crop yields (Iummato *et al.*, 2019; Cavaco *et al.*, 2022).

Cytokinin-based herbicides can actually increase chlorophyll production in plants. Cytokinins are plant hormones that promote cell division and growth and can also stimulate the production of chlorophyll in plants. In addition, certain herbicides can affect the production and activity of photosynthetic pigments, such as carotenoids, which can also affect photosynthesis and plant growth (Jain & Sandhu, 2019).

However, it is worth noting that the effect of herbicides on soybeans can also depend on factors such as plant age and environmental conditions. For example, young soybean plants tend to be more sensitive to herbicides than mature plants, and high temperatures and drought stress can exacerbate the negative effects of herbicide applications. Also important is that the effect of herbicides on photosynthetic activity can vary depending on the specific herbicide, application rate and timing, plant species, and environmental conditions such as temperature and humidity. Therefore, it is extremely important to carefully consider the use of herbicides in agriculture and minimize their negative impact on photosynthesis and plant growth, which is confirmed by the research carried out.

CONCLUSIONS

It has been established that the yield of soybean depends on the weediness of the crops, and when using herbicides, it is possible to prevent crop yield loss and increase its growth. Over the course of the two-year study, it was found that the highest average yield of soybean grain, 29.0 tons per hectare (t/ha), was obtained when using the herbicide Primekstra TZ Gold 500 SC c.s. at a rate of 4.5 liters per hectare (l/ha). The lowest yield rate of 27.3 t/ha among the herbicide options was

obtained when the herbicide Pulsar 40 s.c. was applied post-emergence at a rate of 1 l/ha.

The application of the herbicide Primekstra TZ Gold 500 SC c.s. did not result in a reduction of photosynthesis, and the number of pigments in soybean leaves did not show a significant difference compared to the control. However, in the variants where the herbicides Kommand k.e. and Pulsar s.c. were used, a slight decrease in pigment levels was observed immediately after the herbicides' application, followed by stabilization. In contrast, the introduction of the herbicide Concur c.s. led to a decrease in photosynthetic activity and a reduction in pigment levels. This suggests that the active ingredient metribuzin lacks complete selectivity for soybeans, implying that there is a potential for crop suppression when it is applied.

Prospects for further research consist in studying the use of tank mixtures and compositions for applying soil herbicides with post-emergence herbicides in soybean crops.

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CONFLICT OF INTEREST

None.

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Гербіцидний вплив на агроценоз сої та її фотосинтетичну активність у Західному Лісостепу України

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Анотація. Застосування гербіцидів може суттєво впливати на процеси фотосинтезу рослин, оскільки призводить до пригнічення утворення пігментів, погіршує транспорт електронів у дихальному ланцюзі та фіксацію вуглецю. Мета дослідження – визначити вплив застосування гербіцидів на забур'яненість та фотосинтетичну активність сої. На основі польового дослідження в умовах Навчально-наукового центру Львівського національного університету природокористування встановлено залежність урожайності сої від рівня забур'яненості посівів культури. Найбільшу врожайність сої – 29,0 т/га було отримано при застосуванні гербіциду Primekstra TZ Gold 500 SC c.s. (4,5 л/га), найменшу – 27,3 т/га серед варіантів досліду було отримано при післясходовому застосуванні гербіциду Pulsar s.c. (1 л/га). Застосування гербіциду Primekstra TZ Gold 500 SC c.s. не впливало на інтенсивність фотосинтезу, а кількість пігментів у листках сої достовірно не відрізнялася від показника на контролі. Застосування препаратів Kommand k.e. та Pulsar s.c. призводило до незначного зниження кількості пігментів у перші дні після внесення та поступової їх стабілізації. Застосування гербіциду Concur c.s. призводило до послаблення фотосинтетичної активності та зменшення кількості пігментів. Це свідчить про те, що діюча речовина метрибузин не є абсолютно селективною щодо впливу на рослини сої, тобто в разі її застосування існує ймовірність пригнічення культури. Практична значимість одержаних результатів полягає у розкритті можливостей вибору ефективних гербіцидів з підвищеною селективною фітотоксичністю, які забезпечують ефективний контроль чисельності бур'янів за мінімальної ймовірності негативного впливу гербіцидів на агроценоз сої

Ключові слова: соя; пігменти; діюча речовина; фотосинтез; бур'яни; продуктивність

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Marketing analysis of the functioning environment of agrarian enterprises

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Abstract. Before the full-scale invasion of the russian federation, the agricultural sector of Ukraine developed dynamically and played a leading role in ensuring domestic and global food security, employment of the population, and the formation of foreign exchange earnings from product exports and state budget revenues. The active phase of the war on the territory of the country radically changed the conditions for the functioning of agricultural enterprises. The purpose of the article is to characterize and assess the influence of certain elements of the external environment on the activities of agricultural enterprises. The research is based on the dialectical method of learning economic processes and the following methods are used: monographic, abstract-logical, PEST analysis, SWOT analysis. The study analyzed the works of Ukrainian scientists on the problems of the functioning of agricultural enterprises and identified the main political, economic, social and technological factors of the influence of the external environment on their activities in the conditions of martial law. It has been established that the political factors of the environment affect the activity of agricultural enterprises mainly positively, economic factors have a mainly negative effect on them, and social and technological factors have different directions. The assessment of the main strengths and weaknesses, opportunities and threats of the environment of agricultural enterprises showed the existence of prerequisites for the quantitative growth of gross volumes of their production and the need to develop a comprehensive strategy of agricultural policy for long-term growth in the conditions of post-war recovery, the key tasks of which should be ecologically oriented nature management, the development of dual education for training highly qualified workers, increasing the volume of production and export of organic and ready-made food products, technical and technological modernization of the production base. Priority stimulation of investments in increasing the volume of production of organic food products, development of primary and advanced processing of agricultural raw materials inside the faucet is proposed. The practical significance of the research lies in the fact that its results can be used by state institutions responsible for the development of the agrarian sphere, when developing a strategy for its development and substantiating measures for its implementation, by agricultural enterprises – when developing marketing strategies, by scientists – when further researching the problems of the influence of the external environment on the development of agricultural production

Keywords: agrarian sphere of economy; food; factors of the external environment; martial law

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INTRODUCTION

The agricultural sector plays an important role in the national economy of Ukraine. The enterprises included in it are forced to work under the constant influence of factors of the external macro- and microenvironment. With the beginning of the full-scale armed invasion of the russian federation on the territory of Ukraine, the conditions for the functioning of the economy changed radically, and new challenges arose arising from the war. Constant monitoring of changes in the external environment, uncontrolled by individual business entities, allows them to develop their own strategies for further activities aimed at minimizing the consequences of negative impact factors and maximizing the use of favorable factors. Tracking and forecasting the possible consequences of environmental influences on the economic behavior of agrarians and the results of their activities is the basis for the development of economic policy measures for the maximum use of the potential of the agrarian sector in the conditions of martial law.

If consider the enterprise as a system, then its external environment is understood as a set of all components that do not belong to this system and whose changes can cause the system to transition to a state different from the current one (Drabik, 2022). The external microenvironment consists of factors in the immediate environment of the enterprise that affect its activities. These include suppliers, marketing intermediaries, competitors, customers and the public. The macro environment consists of larger social elements that influence all factors of a company's micro environment, such as demographic, economic, natural, technical, political, and cultural influences (Singh *et al.*, 2022). The complexity of the external environment is reflected not only by the number of its factors, but also by their regional differences and dynamism. The same factors shape different environments in different geographic regions and, at the same time, are quite variable over time (Manic *et al.*, 2017).

All factors of the enterprise's external environment are directly interconnected. Political factors determine the institutional environment of the functioning of the economy, the importance and influence of which on the development of the agricultural sector of Ukraine lies in the possibility of providing enterprises with investment resources through the use of appropriate economic mechanisms (Bakhur, 2020; Zoria *et al.*, 2020; Kravchenko, 2020). This environment determines the presence of innovative technologies through the regulation of the processes of formation and use of innovative knowledge, the state of the market for innovative products, and the level of protection of intellectual property objects (Tesheva, 2020). Collectively, this determines the trends in the development of social capital in the agrarian sphere (Hrytsaienko, 2020). The military actions on the territory of Ukraine radically changed the conditions of the external business environment, which actualizes the chosen research topic.

The purpose of the article was to determine the most influential factors of the external environment of Ukrainian agricultural enterprises during the full-scale invasion of the russian federation and to assess the nature of their influence.

MATERIALS AND METHODS

The research is based on the dialectical method of understanding economic processes, which determined its logic and stages. At the first stage, using the monographic method, the works of Ukrainian and foreign scientists on the problems of analyzing the external environment of enterprises and the development of the agrarian sector of the economy were analyzed, as well as analytical information of the Ministry of Agrarian Policy and Food of Ukraine, the State Statistics Service of Ukraine, the National Institute of Strategic Studies and materials of periodicals.

At the second stage, using the PEST analysis, the main political, economic, social and technological factors of the influence of the external environment on the functioning of agricultural producers were identified and the nature of this influence was determined. The choice of this method is due to the fact that PEST analysis is a powerful and widely used tool for understanding strategic risks. It allows identifying changes and the impact of the external macro-environment on the competitive position of enterprises. Quantitative assessments of the impact of environmental factors were not used due to the significant diversity of product specialization, size, and location of agricultural enterprises.

At the third stage, based on the results of the generalization of the work of Ukrainian scientists regarding the factors that contribute to or complicate the conduct of agrarian business and the results of the PEST analysis, the main strengths and weaknesses, opportunities and threats of the external and internal environment of agricultural enterprises were determined by the SWOT analysis method. On its basis, potential growth opportunities (opportunities) and external factors that may pose risks (threats) are determined. This information is critical to developing strategic plans, setting goals, and making informed decisions to maximize agribusiness productivity. In the study, agricultural enterprises are understood as a set of economic entities engaged in agricultural production and related enterprises for the processing of agricultural raw materials into food products and into raw materials for further industrial use, which cover the stages of reproduction – the production and distribution of the produced product between processing industries. The result of the conducted

research is the formulation of conclusions and recommendations using the abstract-logical method.

RESULTS

In order to understand the threats and opportunities of the external environment for agricultural enterprises, during the PEST analysis, Ukrainian scientists in the pre-war period distinguished a different composition of factors within four main groups of macro-environmental factors: political, economic, social and technological. V. Khodakyvskyy & M. Mysevych (2017) structure each group into six components, and identified economic factors as the most favorable for the development of agribusinesses, while social factors are the most threatening. I. Gorbacheva (2016) assesses the impact of the external environment as mostly negative and identifies six components within economic factors, five political factors, two technological factors, and three social factors. A different approach was used by N. Sirenko & K. Mikulyak (2020), who identified three favorable and three threatening factors within each of the groups. According to the results of their assessments, the threats of the economic bloc have the greatest impact on the development of the agrarian sector. There are no fundamental contradictions in the list of factors in the cited studies, only the degree of their detailing differs. Differences in estimates are due to the fact that scientists used the method of expert evaluations and the result was determined by an optimistic or pessimistic vision of the potential result of the influence of factors.

The views of the agrarians themselves regarding the factors most restraining agricultural activity partially reflect the results of the survey of agricultural commodity producers conducted periodically by the State Statistics Service of Ukraine (2023) (Fig. 1). According to them, for the 1st quarter of 2023, weather conditions were noted by a higher percentage of respondents than lack of financial resources. At the same time, the negative influence of "other factors" under which the majority of respondents point to the war with the russian federation, which complicated the logistical component of exporting products, and therefore negatively affected the price offers of buyers of certain types of products, exacerbated the personnel problem (mobilization of workers).

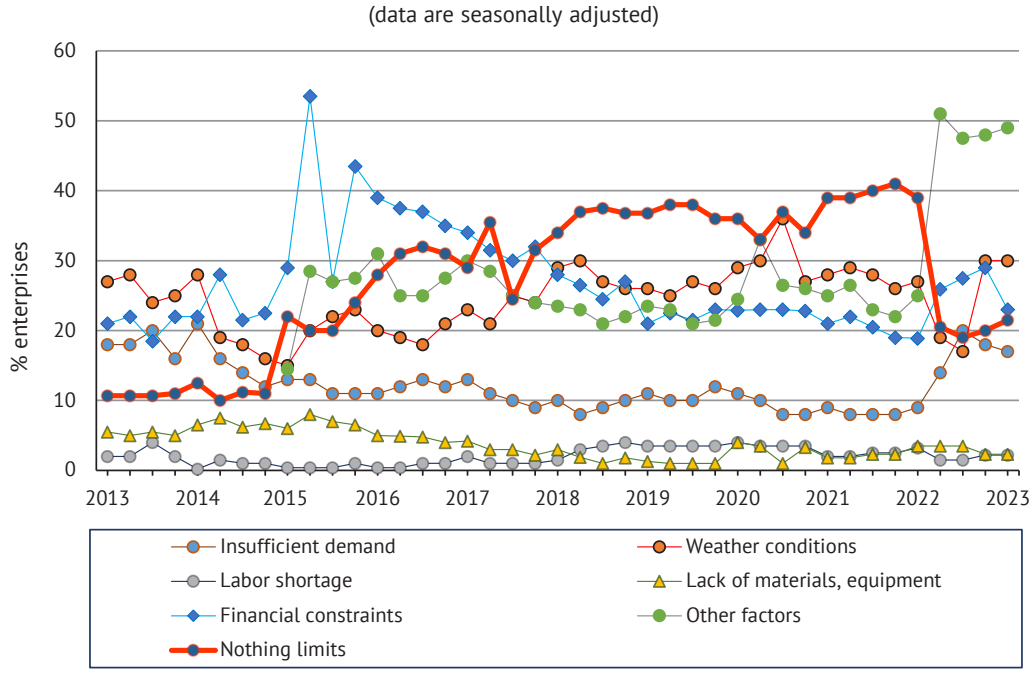

Figure 1. *The results of a survey of agricultural commodity producers regarding factors that complicate the conduct of agricultural business*

Notes*: data for 2023 are provided for the 1st quarter*

Source*: developed by the authors based on the State Statistics Service of Ukraine (2023)*

Political factors of influence. To mitigate the negative impact of the war on agribusiness, Ukrainian government officials and foreign partner countries developed a number of measures. Thus, in 2022, four laws and 11 resolutions of the Cabinet of Ministers of Ukraine (CMU) were adopted, aimed at exempting goods used for the storage of grain and/or oilseed crops, simplifying land relations, registration procedures for agricultural machinery, and seed certification from import duties, farmers' access to fuel, pesticides and agrochemicals, import of food and feed, products of animal and plant origin, genetic material, pesticides and agrochemicals. State financial support programs for agribusiness were also implemented, in particular, within the framework of

the grant program for the creation of greenhouses and gardens, according to the Ministry of Agrarian Policy and Food of Ukraine, in 2022, grants in the amount of UAH 421.3 million were provided. In March 2022, the CMU expanded the "5-7-9% Available Loans" program. Farmers received up to UAH 60 million at 0% annual interest, and state guarantees were provided for 80% of the amount. Under this program, in 2022, more than 34,500 farmers received loans worth UAH 73 billion 351 million. (Ministry of Agrarian Policy and Food of Ukraine, 2023). In 2023, the Ukrainian authorities continued the operation of special programs aimed at supporting Ukrainian producers of agricultural products. Agricultural producers will be able to apply for state subsidies, targeted, subsidized credit programs, loans and technical assistance from the EU and other international donors on the online platform State Agrarian Registry (n.d.).

The assistance of the governments of the partner countries to Ukrainian farmers during martial law consisted in the simplification of export rules, in particular the cancellation by the EU for one year of all customs duties and quotas for exports from Ukraine, the launch of "Solidarity Paths" and the allocation of 1 billion euros for their development, the introduction of various financial assistance programs. For example, since September 1, the State Agrarian Register has started accepting applications within the framework of the new program of assistance to small agricultural producers for a total amount of more than 1.5 billion hryvnias, which is financed from EU budget support (Gromov, 2022). The Food and Agriculture Organization of the United Nations (FAO) also implements programs to support small Ukrainian farmers. They received winter wheat seeds to ensure production needs for the 2023 harvest, as well as grain sleeves (more than 30,000 plus 105 sets of special equipment for their loading/unloading) to ensure storage and protection of the crop this season. FAO provides animal feed, multipurpose cash assistance and vouchers for the purchase of other inputs to rural households. In 2022, FAO allocated $2.4 million to purchase vegetable seeds, grain seeds, and potatoes for Ukrainian farmers (Ministry of Agrarian Policy and Food of Ukraine, 2022).

Against this background, from a political point of view, the growth of Ukraine's authority in the international arena, its support by international organizations, and the consolidation of political forces in the middle of the country are positive. The aggression of the russian federation pushed the population of Ukraine on the path of unification, growth of national self-awareness, popularization of cultural and historical values. During the martial law, a large part of citizens and civil servants realized that overcoming corruption is an extremely important task, because this will be the basis for further victory, effective reconstruction and full and rapid integration into the European Union (Motlyakh, 2022). At the same time, if at the first stage of the war the problems of corruption decreased in urgency due to the scale of security threats, they gradually became relevant again. This was facilitated by the suspension of the public work of the register of electronic declarations of officials and officials, the permission of the Cabinet of Ministers to enter into direct contracts for public procurement, disregarding competition, restrictions on the operation of open data portals, websites of local self-government bodies and their divisions, which reduced the amount of available information about the work of local self-government bodies, in including in the part of decisions regarding the conclusion of lease agreements, provision of residential premises, purchases, etc. (Transparency International Ukraine, 2022).

Economic factors of influence. According to the results of 2022, the Ministry of Economy of Ukraine estimated the fall in GDP to 29.2%, which was a consequence of the destruction of some industrial enterprises in the east of Ukraine, crop theft in the occupied territories and other consequences of the war (GDP fell by…, 2023). At the same time, in 2023, as a result of the relaxation of part of the enterprises, the adaptation of business entities to conducting business in war conditions, as well as the effective actions of the Armed Forces of Ukraine (AFU) to de-occupy the territories, a small increase in the Gross Domestic Product (GDP) is predicted, which is provided for by Law of Ukraine No. 2710-IX (2022) in the amount of 3.2%, forecast by the National Bank of Ukraine (NBU) (2023) by 0.3%. At the same time, the international rating agency Moody's predicts that Ukraine will experience a slight reduction in real GDP by 2% in 2023 (Moody's downgrades Ukraine's…, 2023). The consequence of a possible further recession of the economy may be a reduction in the business activity of agro-enterprises; instead, the slight revival of the economy as a whole predicted by government institutions will not lead to significant growth.

According to the National Bank of Ukraine (n.d.), the consumer price index for 2022 reached 26.6% (December to December of the previous year), and according to the forecast of the Ministry of Economy of Ukraine at the end of 2023, the inflation rate will be 24% (The Ministry of Economy predicts…, 2023). Therefore, it can be expected a further decrease in business income and savings, an increase in production costs, and an increase in the cost of loans.

Predominance in the pre-war period in the structure of the export of products of the agricultural sector of the raw material component in combination with significant logistical problems of its supply to foreign

markets in conditions of war, dependence on the operation of the so-called "grain corridor" when selling to the traditional sales markets of Asian and African countries, limited capacity the European boundaries of the volume of demand in combination with the reduction of Ukrainian elevator capacities to preserve the harvest creates a threat of increasing disparity in purchase prices for export products of agricultural enterprises and, as a result, a significant underachievement of profits.

The threat outlined above is partially offset by the consistently high and growing demand for agricultural products on international markets, which is due to the increase in the global population, which, according to UN forecasts, will reach almost 10 billion people by 2050 (United Nations, n.d.). Given the limited amount of agricultural land, it is impossible to significantly increase the global food supply in the short term, which leads to an increase in market prices. For example, the FAO cereal price index increased by 17.9% in 2022 (De La Hamaide, 2023).

An additional test for Ukrainian farmers is a permanent shortage of resources: fuel in the spring of 2022, electricity in the fall of 2022 and in the winter of 2023. It is clear that these deficits were overcome by the abolition of state regulation of fuel prices and the purchase of generators, but this led both to the loss of part of the production and to an increase in its cost price. As for nitrogen fertilizers, some farmers had stocks for the 2022 sowing season, and at the beginning of the 2023 sowing season, their deficit on the market amounted to more than 60%. According to Taras Vysotskyi, First Deputy Minister of Agrarian Policy and Food of Ukraine: "if a farmer applies 30% less fertilizer or more, then the fall in yield may be twofold" (Fertilizer deficit: Yields…, 2023). It is possible to predict the negative consequences of the disruption of interregional production ties for the volume and structure of agricultural production in the future.

Military operations also had a negative impact on the work of food processing enterprises, some of which temporarily stopped their business at the beginning of the war and began to look for various options for restoring and continuing their activities (How Ukrainian food…, 2023). The destruction of production capacities and the breakdown of logistics chains, the reduction of domestic consumption also affected the demand for the corresponding agricultural products.

Social influencing factors. A key factor in the effective functioning of the branches of the national economy is the availability of highly motivated labor resources, which is manifested through their satisfaction with a decent level of income, the development of social infrastructure, a positive psychological climate at the workplace, etc. According to the International Labor Organization, before the beginning of the military aggression of the russian federation, 15-17 million people of working age lived in Ukraine. A significant number of them lost their jobs in 2022, as hostilities take place in areas where industrial production was mainly concentrated (Vinokurov, 2022). It is quite difficult to accurately determine the number of such people, due to the lack of relevant studies by statistical authorities, however, according to the estimates of the National Bank of Ukraine, the level of unemployment in the country, as of the beginning of 2023, was about 30% (2.0 million people are looking for work in the middle of the country and more 2.7 million abroad from those who got there as a result of the war, and before that were actively involved in the economy of the state) (Unemployment rate in Ukraine…, 2023). This state of affairs deepens the problem of pension provision for the relevant population. The situation is complicated by the demographic component, which is characterized by a clear tendency towards the aging of the nation.

Thus, according to the UN, Ukraine is among the five countries in the world with the highest rates of population aging (Heyets *et al.*, 2019). Under such a development of the situation, producers of agricultural products are the most vulnerable component of the national economy, since workers in this field already have a fairly high average age, which is rapidly approaching the retirement age. Mobilization had a negative impact on the supply of labor resources, especially machine operators. Farms carrying out economic activities on more than 1,000 hectares of arable land had the opportunity to issue reservations for 50% of employees, while smaller ones were deprived of this (Order of the Ministry of Agrarian Policy and Food of Ukraine No. 223, 2023). Both the former and the latter had to solve the problem of the shortage of relevant personnel independently, and the first step was to involve in the implementation of technological processes people of retirement age who had previously worked for these employers. A significant migration of internally displaced persons from the south-eastern regions of Ukraine should have a positive impact on the state of affairs in rural areas, but the vast majority of them do not have relevant work experience in the agricultural sector.

The state, in the form of executive authorities, and Ukrainian and international public organizations to support displaced persons provide them with various support, including financial support. However, the amounts of payments, as a rule, do not reach the level of the previous incomes of such categories of the population, covering only partially their needs for a grocery basket, housing, etc. (Kurinna, 2023). The situation is also negatively affected by the development of inflationary processes in Ukraine, which exerts pressure on the purchasing power of the population. Thus, the author's analysis of the current state of the food market indicates a significant increase in the level of consumer prices and a decrease in the range of presented product

items, especially for products with a high added value. The reason for this is the loss of part of the production and infrastructure capacities, interruptions in the supply of energy resources, constant missile attacks and other factors, the root cause of which was the war. Another factor in the formation of such a situation is the decrease in the purchasing power of the population, according to experts' calculations, by an average of 40-45% (Druhov, 2022). So, if in 2021 the average monthly income in Ukraine was the equivalent of 500 US dollars, then at the beginning of 2023 it will be 375 (Shapoval, 2022). Under this development, most potential buyers will prefer cheaper products belonging to the basic category (flour, bread, oil, etc.), while reducing the consumption of dairy products, meat (cattle, pigs) and its processing products, in primarily the premium segment, etc. The specified structural shifts in the consumer basket of the lion's share of the population forced food industry enterprises to optimize their product portfolio, which led to a decrease in the volume of purchases of certain types of grain from agricultural producers, namely those that are raw materials for the production of products oriented to the domestic market (How the main sectors …, 2022).

The deepening of stratification of population strata in Ukraine by income level has significant negative consequences for the national economy. Because it affects not only the level of purchasing power, but also the supply of individual industries with labor resources. Thus, according to UN research, under modern conditions of ensuring competitive advantages for the economic growth of both the country as a whole and individual spheres, 64% depends on human and social potential, 20% on natural resources and 16% on capital (Chala *et al.*, 2018). Especially vulnerable in such a situation is agriculture, which is losing its traditional base of human resources due to their migration to cities. This process is caused not only by the amount of wages, but also by the lack of proper development of the components of the social infrastructure. The development of the agricultural sector of Ukraine is positively influenced by the presence of a wide network of specialized educational institutions for the training of the entire spectrum of labor professions and specialties, which continued their activities even in wartime, according to the needs of employers. Thus, as of January 1, 2022, 21 institutions of higher agricultural education and 104 colleges of the corresponding profile and a large number of vocational and technical lyceums were operating in the country (Nikolaienko & Nikolaienko, 2021). However, during the last decade, there has been a steady trend towards a reduction in the number of applicants, which is related to both demographic factors and the possibility of educational and labor migration of the population to other countries.

The mentality of managers and employees, which is characterized by a low level of tax culture and a tendency to shadow incomes, has a significant impact on the development of agrarian business. This situation complicates the work of legal Ukrainian agrarian businesses due to a decrease in their competitiveness, which negatively affects budget revenues and the development of rural areas. Also, this has a significant impact on the deterioration of Ukraine's image, as international partners are familiar with such facts and do not support such approaches to doing business. According to experts (Lebed, 2021), the biggest risk of the existence of the shadow market is that its share will continue to grow further, which will lead to a decrease in investments in promising areas related to the formation of added value.

Technological factors of influence. By the end of December 2022, as a result of military operations in Ukraine, about 20% of agricultural land was damaged. They are either mined, or contaminated with oil products and chemical compounds, or damaged by machinery. The area of such lands continues to increase in 2023, and their return to full economic use will take decades (Decyk, 2022). Such a situation will have a particularly negative effect on territorial communities, whose budgets are formed, mainly, at the expense of income from agrarian business. The next element of resource provision of agricultural production, which suffered the greatest losses, is the appropriate machinery, tools and equipment. Damages caused are estimated at $2.9 billion or concern more than 84,000 positions. In addition, grain storage facilities with a total capacity of 9.4 million tons (excluding those operating in the occupied territories) were damaged, which requires appropriations at the level of $1.1 billion (Naiter, 2022). According to the Ministry of Agrarian Policy, 15-20% of cattle, pigs and poultry were lost due to military operations (Rusan, 2023). Total direct losses of the agricultural sector, including stolen and destroyed finished products, during the year of military operations, according to experts' calculations, amounted to $6.6 billion, which is 23% of the total value of assets of Ukrainian agricultural enterprises (Naiter, 2022). The formation of the added value of agricultural products was negatively affected by the loss of significant amounts of processing capacity. This was especially noticeable in relation to the oil and fat industry, which forced farmers to export oilseeds rather than vegetable fats and other related products (Penkova & Kharenko, 2023). The situation in agrarian business was complicated by logistical problems associated with the limited involvement of sea transport in export operations and the sharp increase in the cost of railway services (Zakharchuk *et al.*, 2021). This led to a situation where a significant proportion of commodity producers sold grain almost at cost price.

At the beginning of the second decade of the 21st century, the supply of agricultural goods producers with equipment and tools was in an unsatisfactory state. Thus, their availability in farms decreased by 40-50% compared to 1990, and the degree of wear and tear was approaching a critical limit. The growth in subsequent years of the productivity of crops and animals, as well as sales prices, primarily of export-oriented types of products, contributed to the increase in the efficiency of agrarian business, which made it possible for business entities to massively direct resources to the purchase of modern models of the necessary equipment. The level of concentration of the land bank became a determining factor in the orientation of farmers to the country of origin of the equipment (Vitiuk & Smetaniuk, 2020). Large-scale enterprises, generating greater profits, preferred new models of foreign-made equipment, and small-scale enterprises – Ukrainian ones. At the same time, in the future, the latter reoriented themselves to the previously used foreign-made equipment, believing that although it costs much more than the Ukrainian one, it is superior to it in terms of quality parameters. A similar situation is observed in relation to seed material and plant protection products. The only difference is that with regard to plant protection products (PPPs), large farms buy original drugs, and small producers buy generics. The qualitative and quantitative increase in the technical potential of agricultural producers contributed to the increase in labor productivity and product quality, automation and mechanization of production processes, which had a positive effect on the cost price of the obtained products. At the same time, a negative point for the national economy is the tendency of Ukrainian farmers to use foreign models of both equipment and agricultural machinery with seed material, provided that appropriate Ukrainian products are available.

During the last decade, farmers began to actively pay attention to the quality parameters of the products they produced, as well as the formation of their management system. They were prompted to do so by growing demands from food industry enterprises and traders, which are subjects of foreign economic activity, and therefore focus on the relevant standards in force in importing countries or those with international status. Another reason is the close relationship between quality parameters and the level of purchase prices. The establishment of close, constructive cooperation between product manufacturers and educational and scientific institutions had a positive effect on the implementation of this task regarding: optimization of technological processes of product production, its primary processing, storage; approbation of crop varieties (hybrids) taking into account regional natural and climatic conditions, doses of fertilizers, use of various plant protection systems; training of personnel in advanced approaches to the performance of professional functions; those.

PEST analysis. Evaluating the impact of environmental factors on the development of agricultural enterprises in general, one should note their multi-vector orientation (Table 1). Each additional month of the war will intensify negative trends in the economic, social and technological environment of the functioning of agribusiness.

Table 1. *PEST analysis of factors of external influence on the development of agricultural enterprises*

Impact factor	Direction of action (+/-)	Impact factor	Direction of action (+/-)
Political		Economic	
1. War with the Russian Federation	-	1. Recession of the economy of Ukraine	-
2. Increasing authority of Ukraine in the international arena	+	2. Inflationary processes in the country	-
3. Support of international organizations, including the UN	+	3. Predominance in the structure of the export of products of the agricultural sector of the raw material component	-
4. Harmonization of Ukrainian legislation with relevant aspects of EU countries	+	4. Stable high demand for agricultural sector products on international markets	+
5. Improvement of the institutional environment for conducting business and foreign trade	+	5. Problems with material and technical support, as well as rising prices for means of production in the agricultural sector	-
6. Presence of desire in society for positive changes in the country	+	6. Disruption of interregional industrial relations	-
7. Presence of facts of corruption	-	7. High investment attractiveness (availability of credit resources)	+
Social		Technological	
1. Problems with the labor force: internal and external migration, mobilization to the Armed Forces, rising unemployment, psychological problems of personnel (work in constant stress and anxiety)	-	1. Loss of a part of land, production, processing and logistics resources due to military actions	-

Table 1, Continued

Impact factor	Direction of action (+/-)	Impact factor	Direction of action (+/-)
2. Growth in the number of food consumers in the world	+	2. Fast rates of renewal of fixed assets	+
3. High level of education of the population and qualification of personnel	+	3. Strengthening the relationship between education, science and production needs of commodity producers	+
4. A decrease in the purchasing power of the majority of Ukrainians and, as a result, a change in consumer behavior to limit consumption to the minimum satisfaction of needs	-	4. Automation and mechanization of all production processes	+
5. Growing national self-awareness of the population, "economic patriotism" in consumption and rapid adaptation of business entities to changing environmental conditions	+	5. Increasing the general level of quality of agricultural sector products	+
6. Deepening the processes of stratification of population strata by income level	-	6. Low demand for domestic scientific and technical and innovative developments	-
7. Low level of tax culture of the population, tendency to shadow incomes	-	7. Reduction of requirements for the quality of part of the resources used in agricultural production (fuel, pesticides, etc.) during the martial law	-

Source: *Compiled by authors based on M. Dergaliuk (2017), N. Pryshliak (2018), G. Pruntseva (2021), M. Nehrey & O. Trofimtseva (2022)*

Realization of the potential of positive factors will be determined, first of all, by the terms of Ukraine's victory in the war and the unchanging support of the government and the support of foreign partner countries and international organizations. This allows us to hope for the further effective development of this key sector of the economy for Ukraine, as it will be able to become a locomotive of post-war reconstruction in the future.

SWOT analysis. According to the obtained results, they have a significant potential for their further development in the context of increasing production volumes (favorable natural and climatic conditions, relatively cheap production resources) and further distribution (geographical location of the country, growing demand in the world). This helps attract investment resources, which makes it possible to create new jobs and new added value. All this will affect the improvement of the economic and social situation in Ukraine. Weaknesses of the agricultural sector include an imperfect regulatory framework, the lack of a systematic approach from the point of view of financial and economic support for commodity producers, and the low productivity of the use of resources by a significant number of enterprises (Table 2).

Table 2. *SWOT analysis of agricultural enterprises of Ukraine*

	Strengths	Weak sides
Internal environment	- availability of fertile land suitable for conducting highly efficient agricultural business; - the terrain is suitable for large-scale production of plant products; - favorable climatic conditions; - low level of land rental cost and cheap labor force; - favorable geographical position of Ukraine from the point of view of logistics; - Ukraine's strong position on international food markets (especially grain and oil); - wide use of advanced global technologies by all subjects of economic activity, regardless of the scale of business; - the management of agrarian enterprises actively adopts advanced international experience both in the field of production and processing, logistics, etc.; - introduction of electronic commerce; - one of the highest levels of profitability in the world; - a high share of the export of agricultural products in the national dimension; - the presence of various industry associations and representatives in legislative and executive bodies, which provides opportunities for lobbying interests.	- the land market is not sufficiently developed; - deterioration of the quality of land resources due to non-compliance with technologies and crop rotation; - the need for highly qualified workers is intensifying; - low level of labor productivity compared to EU countries; - lack of effective financial (including credit) and economic support mechanisms for commodity producers as a whole system, which is manifested in the imperfection of the existing long-term strategy for the development of the agricultural sector; - a significant share of production and processing enterprises (mainly small and sometimes medium-sized ones) use old technologies, slowly update the material base; - the presence of dominant players in certain types of products, which are gradually turning into monopolists (especially in the case of animal husbandry products); - the legal framework is imperfect and has many "bottlenecks"; - imperfection of production and market infrastructure, with a low level of development of its marketing component; - being significant players on the international grain and oil markets, Ukrainian commodity producers practically do not influence pricing in relation to them.

Table 2, Continued

	Opportunities	Threats
Environment	- constantly growing demand on international markets; - increasing productivity of agricultural crops and animals with simultaneous improvement of quality parameters; - significant personnel potential on the labor market; - access to new segments of the international food market (including organic products); - attraction of investments in the agricultural sector due to the development of the land market and demonstration of its consistently high profitability; - ensuring support from international financial organizations and the state of Ukraine.	- high level of inflation; - the escalation of military operations on the territory of Ukraine and, as a result, the aggravation of the political, economic and social crisis; - loss of resource potential due to the outflow of personnel and deterioration of the quality of land resources, which will lead to a decrease in its productivity; - permanent deficit on the market of certain types of resources; - existence of miscalculations in legislative, organizational and other areas of sector regulation; - degradation of the agrarian sector due to a decrease in profitability and curtailment of production of certain types of products; - low level of income of the population and a drop in the solvency of domestic demand; - further tinization of business.

Source: *compiled by the authors based on V. Khodakyvskyy & M. Mysevych (2017), N. Pryshliak (2018), N. Sirenko & K. Mikulyak (2020), G. Pruntseva (2021)*

The use of the potential of the internal environment and the favorable opportunities of the external environment allows only to increase the total volume of production of agricultural enterprises of Ukraine in the short term. For long-term growth, it is necessary to systematically overcome weaknesses and threats, which requires systematic actions of the government to develop a comprehensive strategy for the development of the agricultural sector, the key tasks of which should be ecologically oriented nature management, the development of dual education for the training of highly qualified workers, increasing the production and export of organic and ready-made food products, technical and technological modernization of the production base.

DISCUSSION

The obtained results of this study differ from the conclusions of I. Gorbacheva (2016) regarding the most negative impact on the activities of agricultural enterprises of the social environment and N. Sirenko & K. Mikulyak (2020), who identified the economic environment as the most threatening. This is due to a radical change in the operating conditions of Ukrainian agricultural enterprises during the active phase of the war with the russian federation. The conducted analysis showed that it is the war that generates most of the problems in the economic environment, which, in turn, cause negative trends in the social environment. However, the authors of this study fully share the opinion of M. Nehrey & O. Trofimtseva (2022), who, based on the results of the analysis of the agricultural sector of Ukraine during the war, believe that new challenges create not only difficulties, but also open up new opportunities for the Ukrainian agricultural sector.

As was substantiated in this paper, all factors of the external environment are mutually determined. Therefore, conceptually, one cannot agree with the greatest estimates of the influence of the economic factors of the environment, given in the work of V. Khodakyvskyy & M. Mysevych (2017), devoted to the analysis of the functioning of agricultural enterprises in the context of their economic efficiency. This approach corresponds to their equal importance for the development of agricultural enterprises, which was used in the study of N. Sirenko & K. Mikulyak (2020), aimed at substantiating the methodological toolkit of strategic analysis and developing recommendations for the development of the agrarian sector of the Ukrainian economy in changing environmental conditions.

Agreeing with the list of factors of external influence on the development of the agro-industrial complex (APC) of the regions given in the work of M. Dergaliuk (2017), it can be noted that some of them have lost their relevance precisely because of the dynamism of the external environment over time. These are, for example, the once-current WTO restrictions on entering the world market for Ukraine's agro-industrial complex products, or the possibility of an increase in aggregate demand for domestic agro-industrial complex products in the regions at the expense of population income growth.

The conclusion of the work based on the results of the SWOT analysis confirms the position of G. Pruntseva (2021), who, analyzing the problems of the institutional mechanism of food security, determined that the existing formal and informal institutions need significant reform and improvement, as they should ensure the stimulation of production, the competitiveness of Ukrainian products as on domestic and foreign markets, financial availability of agricultural products for citizens.

Therefore, the dynamism of the external environment of the functioning of agricultural enterprises determines the actualization and growth or reduction of the influence of its individual factors on the effectiveness of their activities.

CONCLUSIONS

The transformation of the operating conditions of Ukrainian agricultural enterprises during the active phase of the war with the Russian Federation forced business and government officials to take a number of adaptation measures to continue production and sale of products not only for the sake of domestic food security, but also to satisfy external demand, filling the critically short state budget. The PEST analysis of factors of external influence on the development of agricultural enterprises showed a mostly positive influence of political factors, which is due to the consolidation of business, the state, partner countries and international organizations in creating prerequisites for the preservation of Ukrainian agricultural production. It can be predicted that in the post-war period, the level of support for agrarians will decrease somewhat, since the vast majority of institutional measures adopted during the active phase of the war were of a temporary reactive nature. The most unfavorable are the economic conditions for conducting business, the complex effect of which leads to a significant increase in the cost of production and the unpredictability of opportunities for obtaining profit from its implementation, which is also confirmed by the results of a survey of agricultural producers, according to which among the factors that complicate the conduct of agricultural business, from 2022, significantly the impact of insufficient demand increased. Social factors affect agribusiness in different directions, but in the post-war period, it is possible to predict a gradual solution to the problems of forming personnel potential and raising the level of citizens' incomes. Among the technological factors, the problem of the loss due to military actions of a part of land, production, processing and logistics resources and the deterioration of the ecological condition due to the reduction of quality requirements for some of the resources used in agricultural production will retain their negative influence in the long term. The SWOT analysis revealed that in the conditions of post-war recovery, it is not enough to quantitatively restore the volume of Ukrainian agricultural production. Ensuring the long-term growth and competitiveness of its products requires directing limited investment resources to increase the volume of production of organic food products, the development of primary and advanced processing of agricultural raw materials inside the tap, which will allow enterprises to receive higher incomes, contribute to the growth of employment of the population and, as a result, increase revenues to the state budget . Prospects for further research are the substantiation of the parameters and mechanisms of structural transformations of the agricultural sector of Ukraine, taking into account the challenges of the external and internal environment of its functioning.

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CONFLICT OF INTEREST

None.

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Маркетинговий аналіз середовища функціонування аграрних підприємств

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Анотація. Аграрний сектор України до повномасштабного вторгнення РФ динамічно розвивався і відігравав провідну роль у забезпеченні внутрішньої та глобальної продовольчої безпеки, зайнятості населення, формуванні валютних надходжень від експорту продукції та доходів державного бюджету. Активна фаза війни на території країни кардинально змінила умови функціонування агропідприємств. Метою статті є характеристика та оцінка впливу окремих елементів зовнішнього середовища на діяльність агропідприємств. В основу дослідження покладено діалектичний метод пізнання економічних процесів та використано методи: монографічний, абстрактно-логічний, PEST – аналізу, SWOT-аналізу. В дослідженні було проаналізовано праці українських науковців щодо проблем функціонування аграрних підприємств та виокремлено основні політичні, економічні, соціальні й технологічні чинники впливу зовнішнього середовища на їх діяльність в умовах воєнного стану. Встановлено, що політичні фактори середовища впливають на діяльність агропідприємств переважно позитивно, економічні фактори здійснюють переважно негативний вплив на них, а соціальні і технологічні різноспрямовано. Оцінка основних сильних і слабких сторін, можливостей та загроз середовища агропідприємств показала наявність передумов для кількісного зростання валових обсягів їх виробництва та необхідність розроблення цілісної стратегії аграрної політики для довгострокового зростання в умовах повоєнного відновлення, ключовими завданнями якої повинні бути екологоорієнтоване природокористування, розвиток дуальної освіти для підготовки висококваліфікованих робітничих кадрів, нарощування обсягів виробництва та експорту органічних і готових харчових продуктів, техніко-технологічна модернізація виробничої бази. Запропоновано пріоритетне стимулювання інвестицій в нарощування обсягів виробництва органічних продуктів харчування, розвиток первинної й поглибленої переробки сільськогосподарської сировини всередині крани. Практичне значення дослідження полягає в тому, що його результати можуть бути використані державними інституціями, відповідальними за розвиток аграрної сфери, при розробленні стратегії її розвитку та обґрунтуванні заходів з її реалізації, агропідприємствами – при розробленні маркетингових стратегій, науковцями – при подальшому дослідженні проблем впливу зовнішнього середовища на розвиток агровиробництва

Ключові слова: аграрна сфера економіки; продукти харчування; чинники зовнішнього середовища; воєнний стан

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Unbalanced distribution of income in the conditions of a socio-oriented economy

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Abstract. In global practice, there is a tendency towards uneven distribution of income, and therefore research on many aspects of this topic should be expanded. This study raises the pressing issues of uneven distribution of incomes, which, in turn, creates poverty and social tension among different segments of the population. The purpose of this scientific work is to consider the main reasons for the uneven distribution of income at the end of the 20th and the beginning of the 21st century, which is expressed in the reduction of tax progressivity, the weakening of trade unions, the reduction of competition and monopolisation, globalisation, tax evasion, an ineffective education system, and weak corporate governance laws which allow company management to set unlimited high salaries and much more. To achieve the purpose, the following research methods were used: statistical and economic, abstract and logical, comparative analysis, typological approach, and generalisation. As a result, methods of solving the above-mentioned problems were proposed, including progressive taxation, creation of equal opportunities for obtaining higher education and high-paying work, consideration of state investments in the social sector, creation of means of social mobility, etc. The consequences that uneven income distribution can lead to include political instability, reduced social mobility, crime, low life expectancy, financial instability, economic crisis, etc. This article also includes analytical study of indicators of income distribution equality using the Gini coefficient in different countries. The study represents value for the scientific community and researchers of the issue of income distribution in the conditions of a socially oriented economy

Keywords: unemployment; state regulation; employment; wages; Gini coefficient; standard of living

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INTRODUCTION

The market-based mechanisms of the population's income distribution in society change as a result of the economic system's transformation, which creates the conditions for the population's income inequality to increase. Qualitative and structural changes occur, leading to several social issues because incomes, or rather their uneven distribution, ultimately lead to poverty, one of the most controversial social issues. Additionally, this issue is relative, therefore, there is a need to research the above-mentioned topic in the scientific works of scientists who have studied this issue.

According to K. Mehta *et al*. (2020), although at varying rates, economic inequality has risen over the past few decades in almost every nation, which suggests that institutions and policies play a role in determining disparity. Income disparity has quickly risen in North America, China, India, and Russia since 1980. In Europe, inequality has gradually increased. From a broad historical standpoint, this rise in inequality signals the collapse of a postwar egalitarian government that existed in these areas in various ways. The broad pattern is not always true. Income disparity is still at exceptionally high levels in the Middle East, sub-Saharan Africa, and Brazil. These areas established the "inequality frontier" for the entire world because they were exempt from the postwar egalitarian system.

In the study by K.A. Dolan & C. Petherson-Withorn (2022), who have investigated the issue of wealth, it is noted that the global income distribution by quintile was depicted in a chart by the United Nations Development Programme in 1992. The resulting illustration, which resembled a "glass of champagne", came to represent the wealth gap. The income of the poorest 20% of the population is still less than 2% nearly 30 years later. While this is happening, the income of the richest 1% of the world's population has increased from 18% in 1990 to 22% in 2016, with a $32,000 income threshold being set as the cutoff for this group.

According to T. Piketty (2022), who investigated the historical aspects of inequality, for instance, since the latter part of the 1970s, income inequality in English-speaking developed nations has once more reached the high levels noted one hundred years ago. The indicators have not increased significantly in the countries of continental Europe.

In turn, T.A. Tsalis *et al*. (2020) argue that the 2030 Agenda for Sustainable Development, which consists of 17 objectives for creating more just, peaceful, and sustainable societies, was adopted by world leaders in 2015. One of the goals, Goal 10, is focused on reducing inequality, especially inequality of opportunity, income, and influence because it threatens long-term socioeconomic development, can result in violence, cause disease, and degrade the environment. M. Serra (2022) notes that most of both America, except Canada, is a country with uneven income distribution, according to the UN Secretary general's special adviser on poverty, forgiveness of the poorest countries and control over the spread of diseases in developing countries Jeffrey Sax.

The relevance of this study lies in addressing the pressing issue of income inequality, which has been exacerbated since the 1990s and continues to impact various segments of society. Given the above facts, the purpose of the study is to investigate the main aspects of income inequality in the late 20th and early 21st centuries. The study aims to examine the main factors contributing to this uneven distribution of income, such as reduced tax progressivity, weakened trade unions, limited competition, globalization, tax evasion, ineffective education systems, and weak corporate governance laws allowing excessive executive salaries.

MATERIALS AND METHODS

Using the economic and statistical method of research, the processes of uneven distribution of income in the global economic sphere were investigated, and trends and patterns of their development in a socially oriented economy were identified. Using the aforementioned method, the study has identified the main aspects of the quantitative impact of the decisive factors on the unbalanced distribution of income, and has also identified the key factors that contributed to the establishment of this economic phenomenon. This method was used to determine poverty levels and income growth scenarios in countries with different economic potentials.

The abstract and logical method was used to form theoretical generalisations and conclusions about the unbalanced distribution of income in society. This method was used to summarise the findings and to find ways to address the issue of unbalanced income distribution. Using the abstract and logical method of study of the issue of unbalanced distribution of income in the framework of a socially oriented economy, the paper formulates the main concepts and conclusions on the above issue.

Using the method of comparative analysis, the countries were considered by ranking the value of the Gini coefficient. The Gini coefficient is a statistical measure used to evaluate the level of inequality in the distribution of any variable on a numerical scale from 0 to 1. The coefficient equals 0 if all values are equal (absolute equality), and equals 1 if one value is the maximum and the rest are equal to 0 (absolute inequality). In the context of household income, the Gini coefficient measures the level of inequality in the distribution of income in a given country or region: the closer to one

the coefficient is, the more unequally distributed income is. That is, if all income within the country is distributed evenly, the coefficient is zero, and if one person has everything, and the rest is nothing, the coefficient equals one. Using the method of comparative analysis, the issue of balance and non-compliance with the requirements of world income distribution was considered through the prism of socially oriented economy. In accordance with the method of comparative analysis used in this paper, a comparison of the ways of creating and interpreting the economic status of different layers of society in the period of the 20th-21st centuries was highlighted and presented. Moreover, relying on this method, the paper investigated specific features of the socially oriented economy. Using the method of comparative analysis, the nuances and main aspects of the modern economic environment and future prospects for its development were highlighted.

By using a typological approach in the study of the issue of unbalanced distribution of population income through the prism of socially-oriented economy, the basic aspects of creating the appropriate conditions for creating economic stability were revealed. In addition, using the typological approach, it was possible to determine the relative nuances of the current state of the population's income distribution in the period from the end of the 20th to the beginning of the 21st century. With the help of this approach, it was possible to observe the main aspects of this issue in the study of unbalanced income distribution in the conditions of a socially oriented economy. The method of generalisation allowed considering a number of problems of unbalanced distribution of income in society, through the prism of a socially-oriented economy, and also, based on the above-mentioned method, when studying the conditions of a socially-oriented economy.

RESULTS

The issue of unbalanced distribution of economic resources requires considerable attention and study by 21st century researchers. The modern socially oriented economy is an important aspect for shaping the balance of the economic sphere. From the 1990s to the 2020s, more than a billion people have been liberated from the chains of extreme poverty, demonstrating the significant progress the global community has made in the fight against poverty (The World Bank, 2023). The share of the poorest half of humanity's income has barely changed over this time, despite the fact that global production has more than tripled since 1990 (Purdie, 2019). Economic progress is hampered by inequality, and as a result, the social gap that results from inequality widens, therefore, this issue should be studied more thoroughly.

From the 1990s to the 2020s, inequality has increased in many nations while declining in others (United Nations, 2022). Although inequality rates are still high, there has been a sizable decline in Latin America and the Caribbean. Analyzing the relatively low indicators mentioned earlier, the level of inequality has slightly increased in many industrialized countries. Political changes have caused the level of inequality in a number of Eastern European nations to sharply increase. Even though the gap between various population segments has shrunk overall in some parts of the Middle East, it has nonetheless widened for some sections of the population.

In comparison to trends within regions, there are more parallels between emerging market economies, landlocked developing nations, and rural and urban areas in Africa and Asia. Globally, there are currently more than two thirds of the world's population who are living in increasing income and wealth inequality, which seriously jeopardizes the chances of sustainable development. Children still make up a sizable portion (roughly half) of the world's poor population, despite the fact that targeted efforts to lower child mortality and raise educational standards have produced more effective results in the majority of regions of the world. Other groups that continue to face discrimination and social exclusion include indigenous peoples, migrants, refugees, and other minorities (United Nations, 2019a).

The effects of inequality go beyond just purchasing power. Access to essential services like health, education, water, and sanitation can be hampered by inequality, which can also affect a person's life expectancy. For instance, discrimination, abuse, and lack of access to the legal system can limit human rights. High inequality limits human development, impedes social and economic mobility, and slows economic growth. It also makes feelings of vulnerability, insecurity, and apprehension more entrenched, erodes confidence in institutions and the government, fuels social unrest and tension, and leads to violence and conflict (ITU, 2017).

There is mounting evidence that the extreme wealth and income inequality contributes to the emergence of chauvinistic and extremist-nationalist attitudes. The capacity of people and societies to support efforts to adapt to and mitigate climate change is also compromised by inequality. It will become increasingly challenging to take significant action to combat climate change without addressing the underlying causes of inequality, as demonstrated by populists' response to the introduction of a carbon tax (Lawson, 2018). When it comes to communication, access to financial services, trade, and public services, technology can be a powerful equalizer. However, those who are not yet able to use it

risk experiencing even greater social exclusion, especially as progress stalls or even reverses in some areas (World Inequality Lab, 2018).

In many parts of the world, there is a growing consensus that a narrow focus on economic growth – while ignoring the effects of its distribution – entails a high level of income and wealth inequality. A tenuous relationship exists between poverty and levels of economic inequality, according to the data from the Multidimensional Poverty Index for 2019 (United Nations, 2019a). The data show that middle-income nations are currently home to two thirds of the world's poor Its goals include eliminating discriminatory laws and policies, enhancing methods for regulating international financial markets, promoting safe, orderly, and legal migration, and ensuring that all nations have a greater voice in decision-making at the national and international levels. The poorest 40% of the population's income increased more quickly than the overall population between 2010 and 2016 in 60 of 94 countries with data (United Nations, 2022). Accordingly, inequality is neither inevitable nor irreversible.

Numerous factors, including the stagnation of wages and a decline in the share of labor income, the deterioration of social conditions in developed nations, the lack of social protection in developing nations, changes in the taxation system, the deregulation of financial markets, the rapid advancement of technology, and the automation of production, all contribute to the growing income and well-being inequality.

The variety of trends seen across nations since 1980 demonstrates how different national, institutional, and political circumstances influence the dynamics of income inequality. The various paths taken by China, India, and russia – all former communist or highly regulated nations – illustrate this. As a result of the deregulation and opening-up policies implemented over the past few decades in these nations, the rise in inequality was particularly fast in russia, moderate in China, and relatively gradual in India (Sinquefield & Trump, 2022).

Uneven ownership of capital, which can be either privately or publicly owned, is a major cause of economic inequality. It can be demonstrated that, whether in affluent or developing nations, there have been very significant transfers of wealth from the public to the private sector since 1980. Public wealth in wealthy nations is currently negative or very near to zero even if national wealth has significantly expanded. This might restrict governments' ability to address inequality, and it undoubtedly has significant effects on how equally wealthy people are (Gramm *et al.*, 2022). Countries have become richer over the past few decades, but governments have gotten worse off.

The relationship between net private wealth and net national income provides information on the overall amount of wealth that individuals in a nation control relative to the public wealth that is held by governments. National wealth is equal to the total of private and public wealth. The ratio between public and private wealth is a key factor in determining the degree of inequality. Since 1980, wealth disparity between individuals has risen at varying rates depending on the nation (Biewen & Flachaire, 2018).

Individual wealth disparity is rising as a result of rising income inequality and significant transfers of public wealth to private ownership over the previous forty years. However, neither in Europe nor in the United States has wealth disparity yet reached the heights it did in the early 20th century (Gornick & Jäntti, 2013). In spite of this, wealth inequality has increased significantly in the US, where the wealth share of the top 1% increased from 22% in 1980 to 39% in 2014. The emergence of the top 0.1% of wealth owners was primarily to blame for that spike in inequality. Due in part to the middle class' expanding home wealth and France and the UK's and the United States' lower levels of income inequality, the rise in top-wealth shares in these countries over the past forty years has been more moderate (Drennan, 2019).

Following their transitions from communist to more capitalist economies, China and russia have likewise seen significant increases in top-wealth shares. Between 1995 and 2015, the wealth of the top 1% doubled in China and russia, going from 15% to 30% and 22% to 43%, respectively (Keeley, 2019). The growth in wealth disparity among people has been spurred by a mix of significant privatizations and rising income inequality within nations. The increase in wealth disparity has been more extreme in russia and the US than it has been in Europe. In wealthy nations, wealth inequality has not yet reached the exceptionally high level of the early 20th century (Alford & Reilly, 2019).

Even with relatively strong income growth projections for Africa, Latin America, and Asia over the next three decades, the level of global income disparity will rise if countries continue down the route of increasing income inequality that they have been on since 1980. If all nations adopt the high-inequality track that the United States adopted between 1980 and 2016, then global income inequality will rise even more. However, if other nations follow the EU's inequality track from 1980 to the present, worldwide inequality will only slightly decline (Green *et al.*, 2019).

Up until 2050, there are numerous possible scenarios for income and wealth disparity. Global inequality will rise higher if "business as usual" is maintained in the future. Alternatively, if in the upcoming decades all

nations follow the moderate inequality trajectory of Europe during the past few decades, then there may be a significant improvement in the eradication of global poverty and worldwide income disparity may be lowered (Postma, 2016).

As it can be concluded, there is still a trend in the world to increase the level of uneven distribution of income. This has been especially noticeable since the mid-1990s. For example, as already mentioned, over 20 years (from 1995 to 2015), the income of the richest 1% of people in China and russia has only doubled. Although such a trend has been outlined since the early 1980s. In general, over forty years, as has also been said, the incomes of the richest 1% of the world's people have doubled compared to the total incomes of the poorest half of humanity. For the most part, this is explained by the collapse of egalitarian regimes after the end of the cold war and mass privatization. Although it is that the level of income inequality has not yet reached the level that it was at the beginning of the 20th century. An important aspect of solving the issue of balancing the distribution of income in society and ensuring social equality is the tax policy of the state, as a result of which it is even possible to achieve full employment, and spend significant accumulated funds on creating jobs and social assistance to socio-economically vulnerable sections of the population (Fig. 1).

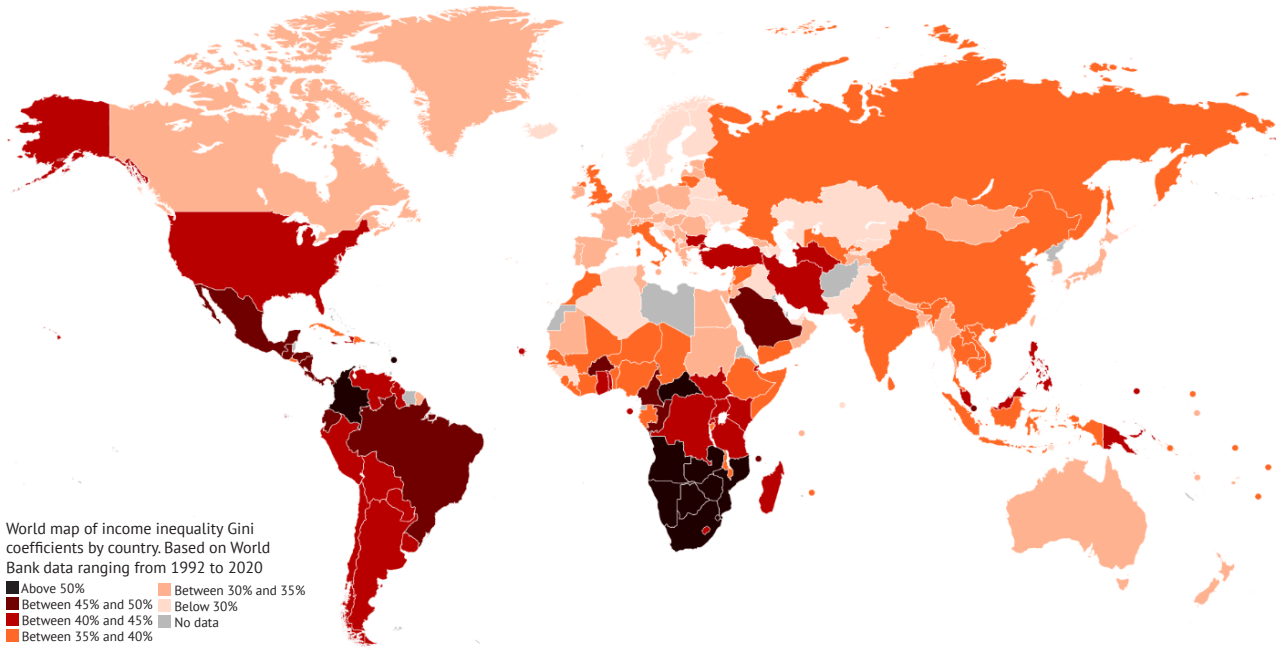

Figure 1. *List of countries by income equality*

Source: *These countries have... (2023)*

As it can be observed, among high-income nations there are some with a sizable middle class, including Western Europe and the Scandinavian nations. Western Europe and the Scandinavian nations prioritize social welfare policies and progressive taxation, leading to relatively higher levels of income equality compared to other regions. These countries have implemented comprehensive welfare systems, education, healthcare, and social services to mitigate income disparities and promote social cohesion. Despite these efforts, some disparities still exist, emphasizing the need for ongoing initiatives to ensure fair and equitable income distribution. Canada has a relatively uniform distribution of income compared to Sweden, Norway, and Denmark. Inequality is also present in Africa and most of Southeast Asia, compared to India. 50 years ago in China, everyone was equal in their poverty. But the rapid development of the economy, the expansion of the gap between those living in urban areas, and those living in a rather poor rural area led to the fact that inequality in China has grown to a level similar to what is marked in the United States (United Nations, 2020). There are various ways of development. So, Northern Europe is on the way to preserve social equality. At the same time, there are also high-income countries with high Gini coefficients, where there is a large gap between rich and poor (Fig. 2).

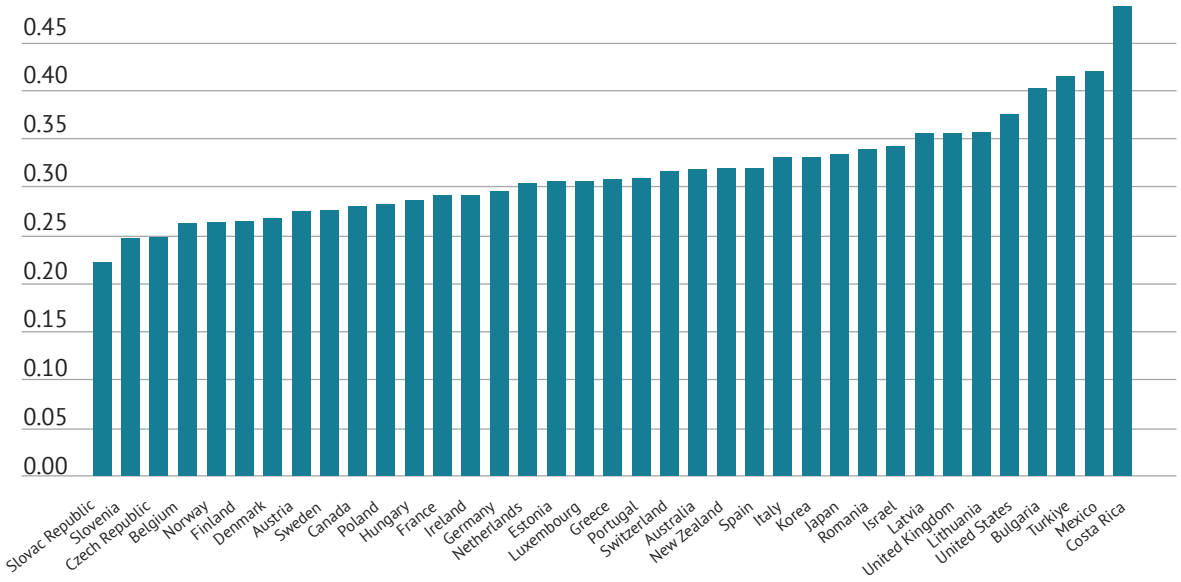

Figure 2. *Gini's coefficient by countries according to the Organization of Economic Cooperation and Development (OECD)*

Source: *OECD (2015)*

Nearly every region of the world has seen an increase in income disparity in recent decades, but at varying rates. The fact that inequality levels vary so widely amongst nations, even when those nations have comparable levels of development underlines the significant roles that national institutions and policies play in determining inequality. Evidently, regional differences in income disparity are significant. Europe has the lowest levels and partly the South America has the highest.

Inequality in the distribution of income can also affect the ability of consumers to purchase goods and services, which reduces market demand and leads to a decrease in production and employment. Thus, an unbalanced distribution of income can threaten economic growth and stability.

The conditions of a socially oriented economy, aimed at ensuring the well-being of all citizens, require taking measures to ensure a fair distribution of income and reduce inequality. This may include establishing a minimum wage, increasing social benefits and assistance to the poor and marginalized groups, developing a tax system that ensures a fair distribution of taxes, and supporting the development of small and medium-sized enterprises that can create jobs and provide economic growth in local communities.

DISCUSSION

Unbalanced distribution of income is a socio-economic phenomenon, which implies a discrepancy between the incomes of different strata of the population. In such a situation, some groups of people receive significantly more income than others, which can lead to increased social differences and inequalities. Inequality is a serious problem that threatens the stability and prosperity of society. Governments and organisations must pay attention to solving this problem and take bold steps to ensure greater equality in society. One of the key measures may be to ensure access to quality education and opportunities for professional growth for all citizens. In addition, it is necessary to ensure equal working conditions and career development opportunities for women and men in order to reduce gender inequality. It is also important to pay attention to the problem of population ageing and ensuring quality care for the elderly, which may become one of the key problems in the future. Focusing on profit and wealth should not be the main goal of the economy and society, and the well-being and care of people should come first. The question of generation and distribution of resources has been investigated by a significant number of researchers all over the world. It is worth considering the views of some of them and comparing them with the results obtained in this study.

In a study by F. Alvaredo *et al.* (2018), attention is paid to the issue of inequality in 2018. Researchers claim that due to factors like income, location, gender, age, ethnicity, disability, sexual orientation, class, and religion, inequality still exists within and between nations and has an impact on opportunities and results as well as access to benefits. This gap is becoming more apparent in some parts of the world. The coverage of new services like the Internet and mobile technologies, however, has gaps. Comparing the research data with the findings of this study, it is worth noting that

inequality in access to opportunities and benefits is a serious problem in the modern world, as the latest digital technologies can be a powerful tool for reducing inequality, but remain inaccessible to many people due to various factors.

J. Hasell (2018) notes that inequality can have different manifestations depending on the country, region, time, and the specific aspect under consideration. Therefore, it is important to study inequality in different aspects and in different contexts to have a complete picture. The authors of this study agree with this statement, as an unbalanced approach to the distribution of economic resources is unique to each individual case.

According to C. Coffey *et al*. (2020), inequality takes different forms and significantly different in different countries. While the objective lay the basis for further action, the fight against inequality should be taken into account the context, economic priorities and political realities of specific countries. There is no universal approach. To eliminate the harmful effects of inequality in all forms and manifestations, the decisive importance will continue to be awareness-raising and providing greater support for policy issues, targeted use and placement of other priorities for public spending to reduce access to benefits and opportunities, reorientation of tax and fiscal systems to reduce income inequality and wealth among the representatives of one generation and between different generations and the use of rapidly changing technologies to benefit all. According to the results of this study, the wealthy stratum of society is quite often involved in the distribution of economic resources, but this situation should be changed and balanced in favour of the population in need of economic support.

E. Ortiz-Ospina & M. Roser (2018) note the fact that both societies and families exhibit inequality. Domestic inequality can account for up to 30% of income inequality. Women continue to be in a much more precarious position from an economic, legal, political, and social standpoint, despite the fact that gender inequality is decreasing – for instance, the gender pay gap has shrunk over the past few decades (United Nations, 2019b). The study agrees with this statement, as it may be related to discrimination, stereotypes about the roles of women and men in society, limited availability of support services for parents and other factors.

In turn, according to M. Van Ham *et al*. (2021) despite China's rapid expansion, inequality has increased significantly on a worldwide scale since 1980. Due to Asia's rapid growth (especially in China and India), the world's poorest half has witnessed a huge increase in income. However, since 1980, the world's top 1% richest people have enjoyed twice as much growth as the poorest 50% of people due to substantial and rising intra-country inequality. For people whose incomes fall between the bottom 50% and top 1% of the global income distribution, income growth has been slow or perhaps non-existent. This covers all lower – and middle-income classes in North America and Europe. The authors agree with the statement, as gender pay inequality between men and women remains an important aspect of the social economy.

Based on the study by T. Piketty (2019), OXFAM estimates that if the inequality persists, it will take a 175-fold increase in global GDP for everyone to have a daily income of more than $5. In order to achieve sustainable development, inclusive, equitable, and growth that balances the economic, social, and environmental facets of development is clearly necessary. Thus, given the globalisation of resources and the development of the digital economy, the issue of equity requires inclusiveness and equal distribution of resources.

Researchers of income inequality in America S.M. Jones & R.S. Rycroft (2023) argue that massive educational disparities, along with a tax system that became less progressive despite an increase in top labour compensation since the 1980s and in top capital incomes in the 2000s, are the main causes of the income inequality trajectory seen in the United States. While wage inequality was also curbed by educational and wage-setting policies that were comparatively friendlier to low- and middle-income groups, continental Europe experienced a slower drop in tax progressivity. Income disparity between men and women has decreased in both regions, although it is still very noticeable at the top of the distribution.

The unbalanced distribution of income in a socially oriented economy in the world is a complex issue and is considered by a large number of researchers, but it is worth noting the fact that the study of the economic sphere is an important aspect of stabilising the global economy, which is oriented towards the values and requirements of the times. Important steps need to be taken to address the problems of economic and gender inequality and to protect the rights and interests of the poorest and most marginalised groups. This can only be achieved through cooperation between governments, civil society, and business.

CONCLUSIONS

Creation of a socially oriented economy that works for all citizens should be one of the top priorities of governments and corporations. This phenomenon implies doing business not only in the interests of increasing profits, but also for socially-oriented purposes, which would include the balanced development of the interests of different social groups. Such an economy involves the use of public funds to provide social services

and programs aimed at improving the quality of life of the population: ensuring access to education, healthcare, housing, adequate income, and other types of social protection.

Gender inequality remains a significant issue despite progress. Women face economic, legal, political, and social disadvantages. Cooperation among governments, civil society, and business is essential to address this and protect marginalized groups. Education, equal working conditions, and career opportunities are key in reducing gender disparities.

As a result of the study, the issue of understanding the pattern of inequality and its reasons is necessary to find ways to create such societies as Western Europe and the Scandinavian, where there is a well-developed middle class and a high chance of every child born in a non-rich family, to get decent education and to ensure their lives. Moreover, the study considered important changes in national and international tax systems are necessary to address income and wealth inequality on a global scale. As a result, it was revealed that many nations require laws relating to corporate governance, education, and pay setting need to be reviewed. Transparency of data is also crucial. Notably, unbalanced income distribution can threaten the socially oriented economy, which aims to ensure the well-being of all citizens and reduce inequality.

The paper managed to investigate the issue of unbalanced income distribution in the socially oriented economy of the late 20th and early 21st centuries from various aspects, but there is still a need to find ways to develop stabilisation of the digital sphere of economic stability and balance of society, as the digital sphere is at the stage of rapid development.

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CONFLICT OF INTEREST

None.

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Незбалансований розподіл доходів в умовах соціально-орієнтованої економіки

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Анотація. У світовій практиці спостерігається помітне зростання нерівномірного розподілу доходів і ця тенденція продовжує зберігатися, у зв'язку із чим дослідження багатьох аспектів цієї теми повинні розширитись. Дане дослідження порушує актуальні питання нерівномірного розподілу доходів, що, своєю чергою, породжує бідність та соціальну напругу у різних верств населення. Мета цієї наукової роботи полягає у розгляді основних причин нерівномірного розподілу доходів наприкінці 20 – початку 21 століття, що виражається у зниженні прогресивності податків, ослабленні профспілок, зниженні конкуренції та монополізації, глобалізації, ухиленні від сплати податків, неефективній системі освіти, слабких законах про корпоративне управління, що дозволяють керівництву компаній встановлювати собі необмежено високі зарплати та багато іншого. Для досягнення мети були використані наступні методи дослідження: статистико-економічний, абстрактно-логічний, порівняльного аналізу, типологічний підхід, узагальнення. У результаті було запропоновано способи розв'язання вище згаданої проблематики, серед яких прогресивне оподаткування, створення рівних можливостей здобуття вищої освіти та високооплачуваної роботи, розгляд інвестицій держави у соціальний сектор, створення соціальних ліфтів тощо. Наслідки, до яких може призвести нерівномірний розподіл доходів, включають політичну нестабільність, зниження соціальної мобільності, злочинність, низьку тривалість життя, фінансову нестабільність, економічну кризу тощо. У даній статті також виконано аналітичну роботу з дослідження показників рівномірності розподілу доходів з використанням коефіцієнта Джині у різних країнах. Робота представляє цінність для наукової спільноти та дослідників питання розподілу доходів в умовах соціально-орієнтованої економіки

Ключові слова: безробіття; державне регулювання; зайнятість; заробітна плата; коефіцієнт Джині; рівень життя суспільства

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Fodder production in Ukraine: Trends, problems and prospects

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Abstract. During the years of Ukraine's independence, the provision of fodder to the livestock industry and their effective use remained a difficult and unsolved problem. The military aggression of the russian federation on the territory of Ukraine, economic, geopolitical, climatic instability, global food crisis exacerbated the pre-war problems and led to the emergence of new threats and challenges in fodder production. The purpose of the study is to assess the state and main trends of the feed market of Ukraine, the problems of the feed industry in the context of modern threats and challenges. The research uses generally accepted methods of scientific economic research, in particular: bibliometric, scientific abstraction and hypothesis, systematic and economic analysis, monographic, analysis and synthesis, complex, abstract-logical, induction and deduction, comparison and logical generalization. The main problems of Ukrainian fodder production were considered: the increase in the cost of material resources, energy resources, the increase in the cost of harvesting and storage of domestically produced fodder, the shortage of labor force due to migration and mobilization, extreme climatic conditions that affect the yield of fodder crops, the quantity and quality of fodder, non-compliance with crop rotation, low feed quality, regional redistribution of feed production and consumption, shortage of working capital, problems with reimbursement of value added tax, delays in customs clearance of imported material resources, high inflation, fixed exchange rate, problematic insurance/letter of credit instruments under export contracts, destruction of the main supply chains in Ukraine, change in the geography of exports, blockade of sea ports, high cost of created logistics chains, difficult access to the market of European countries from the point of view of import and product certification, limitation of throughput capacity of European logistics centers, etc. Attention is focused on the problems of fodder production in the de-occupied and front-line territories: a shortage of resources due to the loss of funds and property due to shelling and theft by the russian military, the destruction of crops, the inability to export products, the death of farm animals due to military actions, damage and destruction of agricultural infrastructure and equipment, the impossibility of conducting technological operations, negative consequences for the land fund as a result of mining, artillery shelling, movement of heavy equipment, etc. The main results of the research can be used for scientific developments and in the practical activities of agricultural producers, assessing the impact of risks and threats on the fodder production industry of Ukraine

Keywords: fodder base; fodder crops; livestock of agricultural animals; feed market

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INTRODUCTION

In solving the problems of socio-economic development of the country, each of the branches of the economy has an important and appropriate place. Some directly create national resources, others create conditions and infrastructure for their production, availability, maximum benefit to all sections of the population. Agricultural production is not only one of the key sectors of the Ukrainian economy, ensuring national food security, but also directly affects the world agro-food sector and global food security. The invasion of the russian federation into Ukraine increased the negative impact after the COVID-19 pandemic, extreme climatic events on the sustainability of the world food system, while recently the role of the Black Sea region in the world food markets has been growing (Abay *et al.*, 2023).

F. Lin *et al.* (2023) analyzed the potential impact of military aggression with duration uncertainty on global food security using a general equilibrium trade model. M. Al-Saidi (2023) notes that the war in Ukraine has led to a serious global food crisis due to complex problems in the supply and increase in prices of agricultural products that arose due to COVID-19 and political and economic difficulties. Crisis phenomena in the global food and fertilizer markets related to the hostilities in Ukraine have large-scale and long-term consequences for price policy and global food security (Hassen & El Bilali, 2022).

In the report "Assessing Food Insecurity in 2022/23 at National and SubNational Levels in 50 Countries Vulnerable to the Effects of the Ukraine-russia Crisis" published by FAO (2022), it is noted that the current conflict between Ukraine and the russian federation increases the risks of further deterioration of the situation with food security at the global level.

In the work of V. Petrychenko *et al.* (2021) stated that the modern feed market is characterized by a reorientation towards the production of high-protein crops to solve the problems of food and feed protein with a steady trend towards the development of agricultural technologies, production and processing. The increase in the productivity of farm animals and the profitability of animal husbandry products requires balanced rations and a reduction in the cost of feed in the cost structure due to the use of high-protein feed. It is important for Ukraine to promote the development of the high-protein and loose feed market on an industrial basis, as well as the development of the production of organic feed and animal husbandry.

Fodder production is one of the elements of the national food chain, which provides livestock with high-quality and safe feed. Taking into account the dynamic development of the agricultural sector, the feed market, economic, geopolitical and climatic challenges, there is a need to research trends in feed production taking into account the risks and threats of modernity. Therefore, the task of this study was a detailed study of the situation in the feed market of Ukraine, as well as an analysis of economic, political, food, global challenges and problems of agricultural production.

MATERIALS AND METHODS

The theoretical and methodological basis of the research is a set of techniques and methods of scientific research, modern economic theory. The information base of the research is scientific developments of Ukrainian and international scientists on the economics of fodder production, legislative acts of Ukraine, official statistical materials of Ukraine, the USA and the EU.

To achieve the goal of the research, general scientific and special methods were used: bibliometric – to determine the state of the researched problem, scientific abstraction and hypothesis; system and economic analysis – to assess the state of the fodder industry; monographic – for assessing the state of feed production in dynamics; analysis and synthesis – to assess the export potential of feed production in Ukraine, determine the factors affecting the feed market; abstract-logical method, method of induction and deduction, comparison and logical generalization, complex method – for summarizing challenges, threats and problems of the fodder production industry of Ukraine, tabular – for illustrating the obtained results, graphic – for visual presentation of economic data, theoretical and methodological research material.

RESULTS AND DISCUSSION

The current state of fodder production is characterized by a decrease in its potential, which occurs against the background of a general decrease in the pace of development of animal husbandry, a decrease in labor productivity in this field due to the limitation of opportunities to update the material and technical base and an increase in the share of the cost of feed in the cost of animal husbandry products (Korniychuk *et al.*, 2021).

The primary task on the way to the formation of a system of sustainable development in Ukraine is to increase the volume of production of animal husbandry products. Ukrainian animal husbandry develops in two ways: extensive and intensive. The first involves the suspension of the process of reducing the number of agricultural animals and the formation of a highly productive herd, the necessary fodder base and decent maintenance. The second is based on increasing the productivity of farm animals due to the effective use of high-quality feed and balanced diets. Today, both the first and the second method remain relevant, since the

situation in animal husbandry is critical and requires not only qualitative, but also quantitative changes.

During the period 2000-2023, the cattle population decreased by 75.6% (including cows by 72.6%), pigs by 34.7%, the poultry population increased by 36%, 2%. However, as a result of the russian invasion of the territory of Ukraine in 2022, compared to the previous year, 15-20% of the livestock of agricultural animals was lost, in particular, the relative decline of the livestock on January 1, 2023 compared to the data on January 1, 2022 was: 15% cattle, of which 12.4% are cows, 10% are pigs and 13% are poultry (Ministry of agrarian policy…, n.d.). In such a situation, producers are forced to reorient themselves, to look for alternative ways to restore the industry. Increasing the number of farm animals for the purpose of solving food security is an extensive way of development, therefore it should take place within rational limits, taking into account the prospects of maximum use of the genetic potential of farm animals.

The livestock sector plays an important role in the development of the agrarian sector of Ukraine, however, in 2021 it occupied an insignificant share in the structure of gross agricultural production – 18.6% against 29.5% in 2010. Its main industries are cattle breeding, pig breeding, poultry farming and sheep farming In 2021, the production of meat and livestock products amounted to UAH 71.6 billion (10.7% more than the level of 2010) or 10.1% of agricultural production at constant prices in 2016. During the period 2015-2019, an increase was observed production of meat of all kinds (State statistics service of Ukraine, n.d.).

The production of poultry meat has achieved a significant increase, which in 2022/2023 MR accounted for 55.2% of the country's meat balance, which is 6.8% more than in 2015/2016 MR. Pork occupies the second place – 30.8%, which is 2.6% less than in 2015/2016 MR. During the period 2015-2023, the production of all types of meat in Ukraine decreased by 9%, in particular, pork by 16.1% and beef by 29.7%, while chicken increased by 3.8% (United States department…, n.d.).

The dairy industry has also undergone fundamental changes, the reduction in the number of cows leads to a decrease in gross milk production, the volume of which in 2022 was 7,160 thousand tons, which is 32.5% less than in 2015. The majority of milk is produced by households – 66.1% in 2022, which is 8.7% less than in 2015 (United States department…, n.d.). The main factors of the decline of the industry are: the unsatisfactory state of material and technical support (including feed) of producers, the imperfection of the mechanism of state and innovative support, the low level of solvency of consumers, cyclical changes in the market, insufficient development of market infrastructure, etc.

At the same time, research by scientists V. Petrychenko *et al.* (2021) and the practice of individual farms shows that this industry is quite profitable and a priority for Ukraine. Along with the negative trends listed above, there is an increase in the productivity of cows, over the past seven years, the productivity of cows in all categories of farms has increased from 4644 kg per year to 5435 kg, or by 17%, even in the conditions of war in 2022, the increase in productivity amounted to 5.4% previous year 2021. It is clear that in agricultural enterprises the productivity of cows grows at faster rates by 14% and 4.5%, respectively (State statistics service of Ukraine, n.d.; United States department…, n.d.). The unstable price situation on the milk market reduces the interest of households in the development of dairy farming.

The main tasks for improving the market of milk and dairy products are: creation of an effective legislative framework for milk processing enterprises; forming a market for high-quality safe feed, stopping the reduction of dairy production, developing a protectionist policy, creating conditions for healthy competition and protecting consumers from low-quality products (Dzhedzhula *et al.*, 2018; Hladiy & Prosovych, 2022).

The development of livestock agribusiness has undergone a complex process, which is associated with an increase in the concentration of the industry in large farms and a decrease in small and medium-sized agricultural enterprises. One of the main tasks for agricultural enterprises specializing in animal husbandry is the organization and formation of the fodder base, which directly affects the level of productivity of farm animals, which depends on their feeding by 50-80%.

Historically, Ukrainian fodder production has never developed as an autonomous industry, although world practice convinces of the real possibilities of producers of various types of fodder to act as independent subjects of both the internal and external agrarian market, focusing on the market environment, the needs of consumers (as producers – animal breeders, as well as various intermediary structures of the trade chain), as well as own production potential and the results of internal marketing research. In contrast to them, households function at the expense of self-sufficiency and the use of public pastures, and in this way maintain a relative balance in the fodder market. However, in general, the transfer of production capacities to households has negative consequences, as it is characterized by an extensive method of management and is based primarily on the high labor intensity of the production process.

The fodder industry is divided into two main areas: field and grassland fodder production. The state of development of field fodder production in Ukraine has remained unchanged over the past few years and is characterised by a reduction in the area under fodder crops.

During the period 1990-2021, the area under fodder crops decreased from 11.9 million hectares to 1.5 million hectares, or by 87%, and during the period 2000-2021 by 78.2%. Over the past 12 years, the area under grasses has significantly decreased: perennial grasses – by 2036.7 thousand ha or 71.2%, annual grasses – by 1489.3 thousand ha or 84.9%. However, the share of perennial grasses in the total area under fodder crops increased by 12.9%, while annual grasses decreased by 7.6%. In general, the share of fodder crops in the total sown area decreased from 26% to 5.4%, or by 20.6%, in 2000-2021 (Fig. 1). The fodder production sector is divided into two main areas: field and grassland fodder production. The development of field fodder production in Ukraine has remained unchanged over the past few years and is characterised by a reduction in the area under fodder crops. During the period 1990-2021, the area under fodder crops decreased from 11.9 million hectares to 1.5 million hectares, or by 87%, and during the period 2000-2021 by 78.2%. Over the past 12 years, the area under grasses has significantly decreased: perennial grasses – by 2036.7 thousand ha or 71.2%, annual grasses – by 1489.3 thousand ha or 84.9%. However, the share of perennial grasses in the total area under fodder crops increased by 12.9%, while annual grasses decreased by 7.6%. In general, the share of fodder crops in the total sown area decreased from 26% to 5.4%, or by 20.6%, in 2000-2021 (Fig. 1).

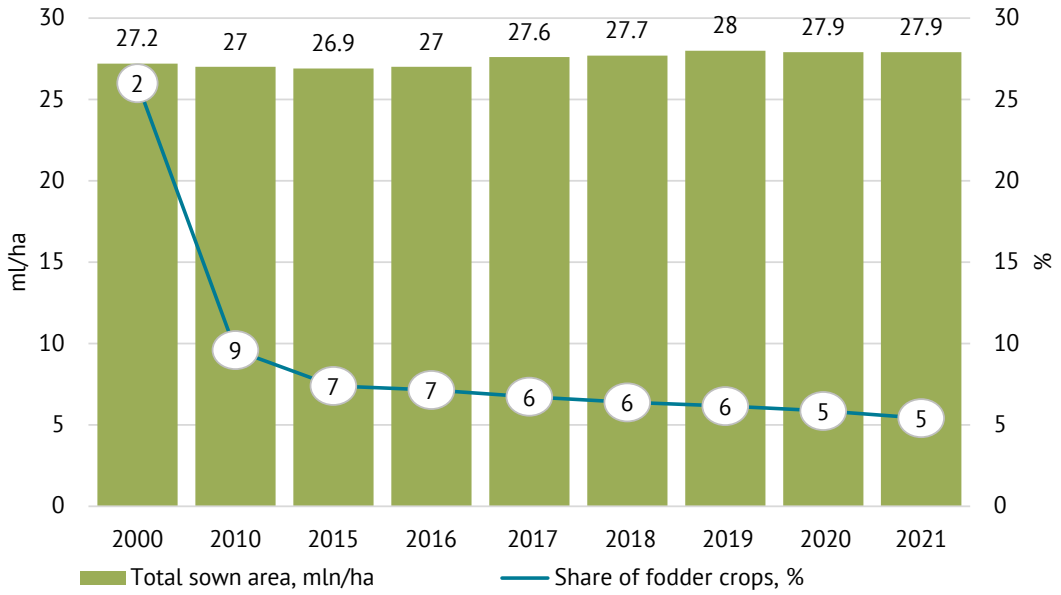

Figure 1. *Share of fodder crops in the total sown area in Ukraine*
Source: *developed by the authors according to the State statistics service of Ukraine (n.d.)*

Modern approaches to the development of fodder production in Ukraine have remained constant, focused exclusively on the course of development of Ukrainian animal husbandry, which determines both quantitative and qualitative criteria for fodder production, its directions, volumes, and prospects. Under such isolated conditions of development, Ukrainian fodder production is deprived of the status of an independent branch of agriculture, which entails gaps in the state's policy regarding the introduction of stabilizing and stimulating measures. At the corporate level, there are also no economic motives for investment interest from both internal business entities and external ones.

Onion-pasture production in Ukraine is just beginning to develop, 7.7 million hectares of fallows, hayfields and pastures require cultivation and the use of agro-innovative technologies. To ensure food security, Ukrainian commodity producers must produce 8,230,000 tons of milk, 135,000 tons of beef, 600,000 tons of pork, 1,620,000 tons of poultry meat, and 14,100 million pieces of meat. eggs With rational feeding of agricultural animals and poultry, 1 ton of fodder should ensure the production of 1 ton of milk with appropriate quality indicators, 0.13 ton of cattle meat, 0.3 ton of pig meat, 0.45 ton of poultry meat and 5.5 thousand eggs. Under such conditions, consumption of livestock products per capita in Ukraine will reach: meat 54 kg (born 83 kg), milk 200 kg (born 380 kg), eggs 280 pcs. (born 290 units). Therefore, in 2023, in order to produce the forecasted volumes of livestock products, the fodder industry must ensure the procurement of bulk fodder at the level of: 1.7 million tons of hay; 7.6 million tons of silage and 8.5 million tons of silage (Hadzalo *et al.*, 2022).

In the structure of the cost of livestock production, feed accounts for the main share of costs, so in the cost of milk, the share of feed is 50-55%, the cost of beef is

65-70%, the cost of products in pig and poultry production is 70-80%, therefore the quality and price of feed directly affect financial condition of animal husbandry. The procurement of high-quality feed that meets the physiological needs of animals and has a high nutritional value is a direct way to reduce the cost of meat and dairy products and improve the economy of the industry. In order to ensure obtaining high-quality grass fodder, it is necessary to strictly follow the basic recommendations for early spring care of fodder areas. (Sidorov *et al.*, 2023).

Provision and effective use of fodder is a complex and unsolved problem of the entire period of reforming the livestock industry, which is constantly in the field of view of scientists and producers. The problems that exist in the field of animal husbandry can be realistically overcome by applying new approaches to intensification in the direction of increasing the level and quality of feeding, transfer of innovations. The basis of the feed base in animal husbandry is concentrated feed, which is evidenced by the dynamics and structure of livestock and poultry feed costs in all categories of enterprises.

The share of concentrated feed in the structure of all feed costs is gradually increasing, which is explained by several factors, including: their high energy value due to the highest protein content among all feed resources; valuable mineral and vitamin composition; the possibility of importing concentrated feed (especially combined) and using it within reasonable limits as an alternative to other types of feed; revival of domestic feed mills. The use of concentrated feeds in animal husbandry has tripled over the period from 2000 to 2021, and their share has exceeded the level of the indicator in 1990. However, the structure of the consumption of concentrated fodder by the livestock industry has changed. According to experts' estimates, in 2020-2022, about 60% of compound feed will be consumed by poultry farms and about 25% by pig enterprises. Cattle account for less than 20% of the combined feed consumed. This is explained by the rapid growth of the poultry population in Ukraine over the past few years and the decline in cattle production and its decline (State statistics service of Ukraine, n.d.). The fodder industry of Ukraine is the key to the development of animal husbandry. The technology of compound feed production includes various types of operations that must be carried out in order to achieve the maximum realization of the potential feed value of feed components. The compound feed market has changed significantly in recent years - many new companies have appeared; fierce competition promotes the development of the feed industry; the main stimulating factor is "price → quality". The production of industrial feed increased over the past seven years until 2019, and from 2020, due to the pandemic, it began to decrease. In general, the total production of compound feed decreased for the period 2015-2021 in all categories by 8.6%, and of feed premixes by 36.4% (Table 1).

Table 1. *Production dynamics of the main types of industrial feed in Ukraine, thousand tons*

Types of feed	2015	2016	2017	2018	2019	2020	2021	Change, %
Compound feeds in total	6192	6232	5984	6025	6464	6302	5657	8.6
- for pigs	1395	1440	1107	1210	1229	1236	1264	9.4
- for cattle	722	738	592	724	701	744	645	10.7
- for poultry	3884	4032	3745	4091	4534	4322	3748	3.5
Premixes for farm animal feed	60.2	52.8	55.3	67.9	78.6	60.0	38.3	36.4

Source: *compiled by the authors based on data from the State statistics service of Ukraine (n.d.)*

The most important task for the development of industrial fodder production in modern conditions is the restoration and improvement of industrial and economic relations both with suppliers of grain and industrial waste during the processing of agricultural products, and with consumers of compound feed. According to experts (Petrychenko *et al*, 2021), the growth of feed production is adequate to the growth of animal husbandry needs, and their deficiency will still be covered by the import of feed components.

In this case, regulatory and legal support of fodder production plays an important role. In 2020, Law of Ukraine No. 2264-VIII "On the safety and hygiene of fodder" (2017), which defines the legal and organizational principles of guaranteeing the safety of fodder in the process of its production, circulation and use, in particular, establishes requirements for hygiene, labeling, packaging and presentation of fodder, regulates relevant public relations between market operators and state authorities.

In the last decade, poultry farming began to develop within large holding agro-formations created on the basis of vertical integration. Such complexes also include combined feed plants, which independently

supply livestock units with fodder, including combined feed. About half of the production of compound feed in Ukraine is accounted for by such compound feed plants. The raw material base for feed mills is formed by producers of grain (corn, fodder wheat) and oil crops (soybean, sunflower, rapeseed). If in 2000, Ukraine produced 10.2 million tons of wheat, of which 16.7% was used for livestock and poultry feed, and only 0.8% was exported, then in pre-war 2021, production increased to 33 million tons (almost in 3 times), for feed – 12.1%, export – 57.1%. Russian aggression on the territory of Ukraine in 2022 caused a sharp decrease in production to 21 million tons (36.4%), the share of domestic consumption increased to 19%, and exports to 64.3% (State statistics service of Ukraine, n.d.).

A similar situation developed on the corn grain market (Fig. 2). During the period 2000-2021, Ukraine increased the production of this crop from 3.8 million tons to 42 million tons or 11 times, exports increased from 10.3% to 64%, and domestic consumption from 57.2% to 18.5%, and overall domestic consumption decreased by 50%. In the last year of 2022, production decreased in relation to the previous year 2021 by 36%, consumption by 48.5%, exports by 16.6%.

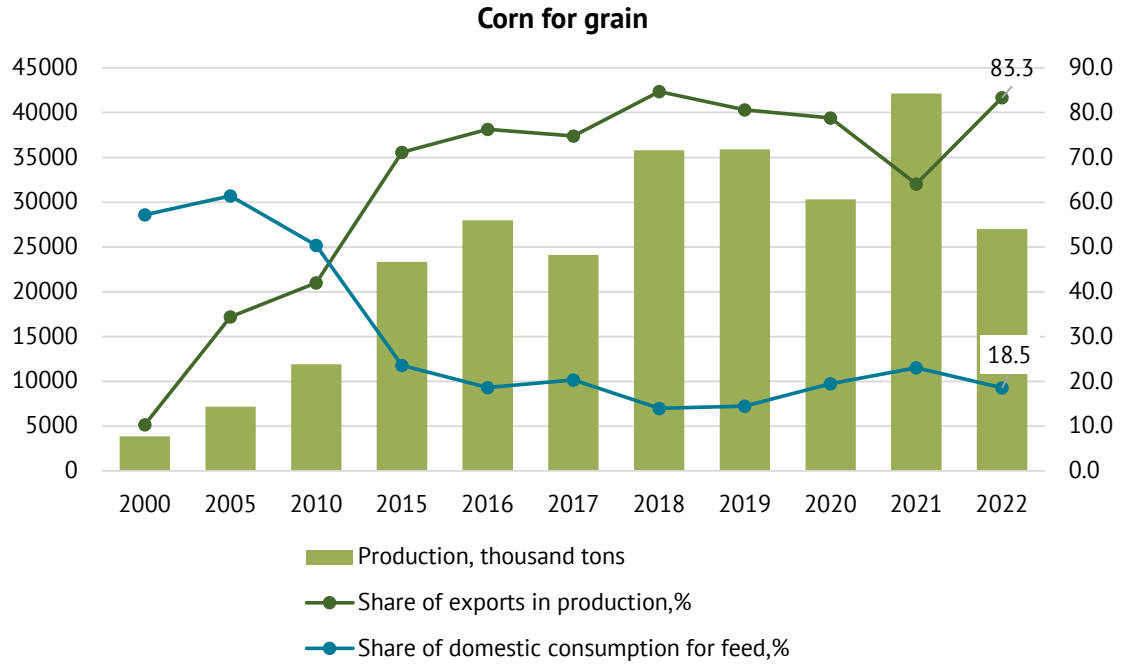

Figure 2. *Production, consumption and export of corn for grain, thousand tons*
Source*: developed by the authors based on the State statistics service of Ukraine (n.d.), United States department... (n.d.)*

Disruption of logistics, export problems, blockade of sea ports, occupation of commodity production zones are the main reasons for destabilization of the grain sector in 2022. In general, during the years of independence, the oil and fat industry developed, where, along with the traditional culture of sunflower, the production of soybeans and rapeseed is developing. The increase in the production potential of these crops occurred due to the expansion of sown areas and increased yields. For the economy of Ukraine, these crops are of strategic importance as both food (oil) and feed crops (meal, cake). Ukrainian sunflower, meal and oil are in demand on the world market and form a significant part of the balance of feed protein on the European market. The value of protein-oil crops as the most important source of vegetable protein and oil increases in connection with the growth of the population, in the formation of food resources, adequate nutrition, improvement of health and prolongation of human life. EU countries import up to 14 million tons of soybeans and 18.3 million tons of soybean meal from the USA, Brazil, Canada, and Paraguay. Ukraine provides EU countries with 37% rapeseed, 73% sunflower meal and 28% rapeseed oil. The use of meal of protein-oil crops in feeding animals and poultry is a new era, the main and strategic direction in the supply of high-protein feed, ensuring complete feeding and increasing their productivity (Petrychenko *et al.*, 2021). In the structure of world meal production, soybean meal makes up 68.4% of all meal. Soybean meal differs from other high-protein ingredients in its balanced amino acid composition, and has feeding features that are still little known in Ukraine. In terms of fodder benefits, soybean meal surpasses all other vegetable sources of protein, has the highest nutritional value, the widest use in feeding, is suitable for all types of animals, poultry and fish.

The use of sunflower and rapeseed meal in the rations of feeding cows, which leads to an increase in the protein content, helps to strengthen the metabolic processes in the animal's body, improves their physiological condition and increases milk productivity. The practice of using these types of meal is quite common in European countries (European Union, n.d.). It is preliminarily estimated that the export of sunflower meal from Ukraine in 2022/2023 MR will make up 77.5% of gross production, which is 4.1% more than the level of 2021/2022 MR (Table 2).

Table 2. *Production, consumption and export of sunflower seed meal, thousand tons*

Year	Sunflower seed meal			Share of exports in production, %
	Production	Domestic consumption	Exports	
2010/2011	3296	390	2927	88.8
2015/2016	4811	1000	3817	79.3
2016/2017	6030	1300	4807	79.7
2017/2018	5679	1300	4238	74.6
2018/2019	6112	1350	4808	78.7
2019/2020	6455	1350	5181	80.3
2020/2021	5679	1275	4396	77.4
2021/2022	4460	1200	3275	73.4
2022/2023	4130	1050	3200	77.5
Growth index	1.25	2.69	1.09	*
Absolute growth, ±	834	660	273	11.3

Source: *compiled by the authors based on data from the State statistics service of Ukraine (n.d.), United States department... (n.d.)*

Since 2010, the total export value of sunflower meal has increased by 9.3% with a 25% increase in production. Ukraine has long held a leading position in the world market of sunflower meal: in 2020/2021 MR – 28%, in 2021/2022 MR – 23.4%, in 2022/2023 it is expected to be at the level of 20.1%.

Canola meal provides an amino acid balance that targets the required amino acid profile of the pig better than any other plant protein (Hein, 2020). The production of rapeseed meal for the period 2010/2011 MR 2022/2023 MR is expected to increase more than 2 times, domestic consumption by only 33%, export by 59%.

Due to the significant volume of solvent demand, the market of the European Union is able to continue to absorb products produced in Ukraine. The needs of the countries of the European Union are covered in protein by only 38% (European Union, n.d.). Taking into account the current trends, we can safely predict a further increase in the volume of deliveries to this market. However, there is a threat that Ukraine will be limited only by production capacity. Therefore, there is a need to shift the emphasis on the processing of grain and oil crops, in particular soybean and rapeseed.

The pre-war problems and challenges of fodder production were complicated by the military aggression of the russian federation from February 2022. Economic, political and ecological instability, the aggravation of the global food problem, led to the emergence of new threats and challenges for fodder production in Ukraine.

Research by scientists V. Petrychenko *et al.* (2022) testify that under the conditions of martial law in Ukraine, logistical connections for the supply of fodder and the sale of livestock products are disrupted, which prompts producers to look for alternative options. Ukraine imported some feed and veterinary drugs, but due to the war and logistical problems, their purchase is currently limited. Production of the projected amount of fodder is complicated by a shortage of energy and human resources, as well as unstable weather conditions.

The current state of the Ukrainian market of fodder and fodder resources calls into question its effective performance of the function of ensuring the food security of the state in terms of the production of livestock products. Feed supply is based on the use of domestically produced feed, increased competition between Ukrainian commodity producers and suppliers of biological feed additives, and the low level of development of industrial feed production (Voronetska *et al.*, 2020). Thus, it is possible to identify a number of key factors inhibiting the development of fodder production in Ukraine (Fig. 3).

Related to production	• the increase in the cost of material resources (fuel and lubricants, mineral fertilizers, preservatives, plant protection products, machinery and equipment) leads to an increase in the cost of feed and a decrease in the profitability of the industry; • rising prices for feed additives; • increase in the cost of procurement and storage of own-produced fodder; • power outages, shortages and high cost of electricity destabilize the work of feed producers, lead to an increase in the cost of production, loss of productivity and disruption of technological processes, therefore modernization of equipment for work on alternative types of energy is necessary for energy independence; • labor shortage due to migration (according to international estimates, the number of internally displaced persons exceeds 7 million people and more than 4 million people registered for temporary protection in Europe) and mobilization, which reflects a huge loss of labor force; • extreme climatic conditions that affect the productivity of forage crops, the quantity and quality of fodder; • adjustment of crop rotations by agricultural producers due to high costs, problems with the sale of products, giving preference to the cultivation of highly profitable crops, which led to a reduction in the area sown under fodder crops. In addition, the households of the population grow little or no fodder crops; • unharvested corn, soybeans, sunflower, which causes the problem of unharvested plant residues, and accordingly, the areas are not ready for sowing; • low quality of feed, due to a high share of cereals in the raw material (for cattle), a low share of alternative types of raw materials, high cost of premixes and additives, which leads to a low balance of feed; • regional redistribution of feed production and consumption.
Related to financing	• deficit of working capital due to the increase in the cost of production, high inflation, unsold harvest of previous years, low price of agricultural products, increase in the price of bank lending due to the increase of the NBU discount rate, etc.; • high level of inflation; • problems with VAT refunds: blocking of tax invoices, significant delays with VAT refunds; • delays in customs clearance of imported material resources (mineral fertilizers, plant protection products, feed additives); • a fixed exchange rate creates additional restrictions, because agricultural means of production are often purchased with a reference to the market rate, while the foreign exchange revenue received by exporters is sold at the interbank rate, which is close to the official rate of the NBU; • distressed instruments of insurance/letters of credit under export contracts.
Related to logistics	• destruction of the main supply chains in Ukraine; • change in the geography of exports due to the disruption of traditional logistics routes; • blockade of sea ports (before the full-scale invasion, 95% of exports were carried out by sea); • created logistic chains, characterized by high cost, due to high cost of transportation, inflation; • restrictions on land routes: lack of drivers for road transport; low capacity of railway stations on the border with European countries; different track widths in Ukraine and the EU; • difficult access to the market of European countries from the point of view of import and product certification; lack of a sufficient number of European wagons for grain transportation; • limiting the capacity of European logistics centers.

Figure 3. *Problems and challenges of the fodder production industry in Ukraine*
Source*: compiled by the authors according to Agribusiness of Ukraine during the war... (2022)*

The military aggression of the russian federation in Ukraine led to an increase in feed and energy prices, a shortage of feed raw materials, and problems in logistics chains, which lead to an increase in production costs. Issues related to the neutralization of the consequences of hostilities in de-occupied regions and front-line territories require special attention (Fig. 4).

Associated with the consequences of hostilities in the de-occupied and front-line territories	• lack of resources due to loss of funds and property due to shelling or theft by the russian military, destruction of crops, untimely harvest, low prices for products or inability to export products; • the death of farm animals due to hostilities; • damage and destruction of agricultural infrastructure and equipment: warehouses, granaries, fodder storage facilities, agricultural machinery and equipment; • occupation of enterprises, theft and removal of crops, machinery, equipment and other means of production; • the impossibility of carrying out technological operations (introduction of chemical fertilizers, fertilizing, harvesting, irrigation) due to the mining of fields and proximity to the combat zone; • negative consequences for the land fund as a result of mining, artillery shelling, movement of heavy equipment; • part of the sown areas, which was not cultivated last year, is characterized by increased weediness, pollution by pests and diseases; • agricultural producers in the front-line territories do not have the opportunity to take advantage of preferential taxation and preferential lending; • lawsuits for non-payment of credit debts; • lawsuits for accrued utility services for enterprises that were under occupation and did not actually consume these services; • increased level of risks of logistics operations in de-occupied and front-line territories.

Figure 4. *Problems and challenges of fodder production in the de-occupied and frontline territories*
Source*: compiled by the authors according to Agribusiness of Ukraine during the war... (2022)*

In order to provide animal husbandry with high-quality fodder balanced by the content of nutrients, it is necessary to develop the fodder production system, including the field and onion-pasture direction (Yurchuk *et al.*, 2022). Increasing the productivity of forage crops can be achieved in two ways: by optimizing the structure of forage crops on irrigated and non-irrigated lands and by using energy-saving technologies for their cultivation (Holoborodko *et al.*, 2020).

Databases of promising breeding material of fodder crops have been formed in Ukraine (The state register of plant varieties…, n.d.). Every year, Ukrainian scientists and breeders create and introduce new high-yielding varieties of forage crops, legumes and grasses with increased quality indicators and productivity. In addition, fodder crops can be used for reclamation of degraded, unproductive and technologically polluted lands, organic farming, etc.

The experience of other countries shows that in the conditions of globalization, commodity fodder production is developing, as the most optimal way of market orientation is the formation of specialized fodder production enterprises to meet the needs of small and medium-sized agribusiness (Sprynchuk, 2020).

I. Cherevko (2022) proposes to apply the Polish experience in the development of fodder production and the provision of livestock feed in Ukraine. Noting that based on the key trends in the development of fodder production in the world, the main ways of its further development in Ukraine relate to increasing the level of their ecological safety, developing the use of active feed additives, in particular of a medicinal nature, optimizing the structure of fodder and feeding animals, improving the quality of fodder and the possibility of changing their structure production, intensification of fodder production by households, – increasing the efficiency of fodder use, specialization in fodder production, innovation and digitalization of the industry, which will become fully possible in Ukraine after the end of hostilities and ensuring the possibility of safe farming in the de-occupied territories (Cherevko, 2022).

To ensure the sustainability of agriculture, local resources for agricultural production and feed production, such as land, forests, water ecosystems, must be protected from pollution and over-extraction of nutrients. It is necessary to improve sustainable agricultural practices by increasing the efficiency of nutrient use, increasing nutrient recycling, reducing waste, increasing agricultural production, reducing greenhouse gas emissions, and increasing agricultural productivity through the integration of industries. The integration of agricultural production has enormous potential to improve nutrient recycling or recovery (Adegbeye *et al.*, 2020). Research confirms that the transfer of innovations of self-renewing agriculture allows for the rational use of natural resources both in terms of ecological and economic components and to achieve effective and long-term growth (Petrychenko *et al.*, 2022).

The significant potential of the feed production industry of Ukraine allows us to meet not only our own needs for feed protein, but also to enter the global

feed market as a supplier of deep processing products. A comprehensive approach with support at the local, state and international levels is necessary to solve the problems and challenges of fodder production and to restore the activities of agricultural producers. It is necessary to carry out the restructuring of sown areas, agro-technological approaches to the technology of growing fodder, use special equipment for demining agricultural lands, consolidate at the international and state levels support for the fodder industry, develop special programs to stimulate the development of animal husbandry, first of all dairy cattle breeding in the small and medium segment agribusiness It is necessary to develop sustainable ecologically safe fodder production, which will contribute to the development of all branches of agriculture and create opportunities for the development of value-added production.

CONCLUSIONS

Animal husbandry of Ukraine plays an important role in ensuring food security and the development of the agricultural sector, although the share of the livestock industry in the structure of gross agricultural production in 2021 is only 18.6%. Cattle population decreased by 75.6% (including cows by 72.6%), pigs by 34.7% during the period 2000-2023. The decrease in the number of cows causes a decrease in gross milk yield, the volume of which in 2022 was 7,160 thousand tons, which is 32.5% less than the level of 2015. The level of productivity of farm animals depends on their feeding by 50-80%, so the main the task of producers is to provide high-quality fodder for farm animals. The development of field fodder production in Ukraine is characterized by a 78.2% reduction in fodder crops for the period 2000-2021. Over the past 12 years, the area sown with perennial grasses has significantly decreased by 71.2%, annual grasses by 84.9%. Concentrated fodder is the basis of the fodder base of animal husbandry, their use in 2021 compared to 2000 has increased three times. The raw material base for concentrated feed is grains (corn, fodder wheat) and oil crops (soy, sunflower, rapeseed).

The military aggression of the russian federation in Ukraine led to deepening of the problems of the agricultural sector, in particular, fodder production. The projected increase in the demand for livestock products requires an increase in feed production. Fodder plays a central role in ensuring adequate feeding of animals. A diet balanced in terms of all nutrients and at a level that meets the production goal, taking into account the animal's physiological state, is a prerequisite for achieving high and sustainable animal productivity.

The production of the projected amount of fodder in the conditions of martial law is complicated by the shortage of energy and human resources. In Ukraine, it is necessary to increase its own production of feed, increase its effective use, which will reduce dependence on imported feed ingredients, as well as reduce the cost of feeding. In conditions of limited resources, the problem of fodder shortage can be solved thanks to sowing of annual and perennial grasses, grain-legume mixtures, grass mixtures, because scientifically based mixtures of fodder crops will be able to almost completely provide nutrients to farm animals and form their own market for fodder. Prospects for further scientific research consist in the formation of measures for the restoration and development of fodder production in Ukraine under the influence of threats created by the military aggression of the russian federation.

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CONFLICT OF INTEREST

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Кормовиробництво в Україні: тенденції, проблеми і перспективи

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Анотація. За роки незалежності України забезпечення кормами галузі тваринництва та їх ефективне використання залишалися складною і невирішеною проблемою. Військова агресія рф на території України, економічна, геополітична, кліматична нестабільність, глобальна продовольча криза загострила довоєнні проблеми і зумовила виникнення нових загроз і викликів у кормовиробництві. Метою дослідження є оцінка стану і основних тенденцій ринку кормів України, проблем кормовиробничої галузі в контексті сучасних загроз і викликів. У дослідженні використано загальноприйняті методи наукових економічних досліджень, зокрема: бібліометричний, наукової абстракції та гіпотези, системного та економічного аналізу, монографічний, аналізу і синтезу, комплексний, абстрактно-логічний, індукції та дедукції, порівняння та логічного узагальнення. Було розглянуто основні проблеми українського кормовиробництва: зростання вартості матеріальних ресурсів, енергоресурсів, здорожчання процесів заготівлі і зберігання кормів власного виробництва, дефіцит робочої сили внаслідок міграції і мобілізації, екстремальні кліматичні умови, які впливають на урожайність кормових культур, кількість та якість кормів, недотримання сівозмін, низька якість кормів, регіональний перерозподіл виробництва і споживання кормів, дефіцит обігових коштів, проблеми з відшкодуванням податку на додану вартість, затримки з митним оформленням імпортованих матеріальних ресурсів, високий рівень інфляції, фіксований валютний курс, проблемні інструменти страхування/акредитивів за експортними контрактами, руйнування основних ланцюгів постачання в Україні, зміна географії експорту, блокада морських портів, висока вартість створених логістичних ланцюжків, ускладнений доступ на ринок країн Європи з точки зору імпорту та сертифікації продукції, обмеження пропускної спроможності європейських логістичних центрів, тощо. Зосереджено увагу на проблемах кормовиробництва на деокупованих і прифронтових територіях: дефіцит ресурсів через втрати коштів і майна внаслідок обстрілів і крадіжок російськими військовими, знищення посівів, неможливості вивезти продукцію, загибель сільськогосподарських тварин через воєнні дії, пошкодження й руйнування аграрної інфраструктури та техніки, неможливість проведення технологічних операцій, негативні наслідки для земельного фонду внаслідок замінування, артобстрілів, руху важкої техніки, тощо. Основні результати дослідження можуть бути використані для наукових розробок і у практичній діяльності агровиробників, оцінюванні впливу ризиків і загроз на кормовиробничу галузь України

Ключові слова: кормова база; кормові культури; поголів'я сільськогосподарських тварин; ринок кормів

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Marketing communication in the context of the optimal model of the national pattern system of waste management in Ukraine

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Abstract. The issue of rational waste management in Ukraine is quite acute. The system is in a state of decay, because about 94% of waste ends up in landfills and, at the same time, has a negative impact on the environment. That is why the issue of building a perfect management system and applying marketing communications in Ukraine is quite relevant, because proper waste management with the help of marketing measures will not only save the environment, but also attract secondary raw materials to energy or further production. The purpose of this work was to research and generalize the aspects of marketing communications in the context of the optimal model of the national pattern system of waste management in Ukraine. The research used a system method, an analysis method, and complex and integrative methods. It was determined that the level of volumes of generated and accumulated waste in Ukraine is quite high. It has been established that it is necessary to develop and improve measures for the disposal of acid, alkali or salt waste, other mineral waste, chemical waste, industrial waste sludge, ferrous metal waste and mixed and undifferentiated materials. Necessary waste disposal measures have been determined, which in turn should provide an opportunity to organize complex waste processing measures and ensure the use of their energy potential. The marketing communications established in the study will help to implement measures to stimulate recycling enterprises by the state, to establish relationships between producers and consumers of secondary products, to provide informational support for waste processing through the media, to create a marketing complex around secondary products and to reproduce the use of secondary products in energy efficiency. The recommended structure of marketing communications for running a waste management business in Ukraine will bring recycling to a new level and increase its efficiency. The practical significance of the study is that the identified waste disposal measures and accompanying marketing communications can be used in Ukraine to improve the effectiveness of the waste management system

Keywords: marketing communication; waste management; advertising; trends; transformation of social values

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INTRODUCTION

The environment is in a permanent system of a closed cycle, which in turn is accompanied by the transition of substances from one state to another. The functioning of economic processes is based on the circulation of resources, which consists in their production, use and generation of waste. Since the 2010s, the issue of waste management has intensified, because imperfect management in this area has a negative impact on the environment. M.O. Barinov *et al*. (2021) determined that the rational management of waste is quite important today, because it can not only be destroyed, but also processed and used as raw materials for subsequent sales products. Waste management is considered by the authors as a systematization of waste management methods and measures, which should primarily be the most favorable for the environment. At the same time, waste management should take place as close as possible to the source of its generation, prevent environmental risks, have large-scale efficiency, ensure the independence of disposal processes and be based on joint responsibility.

Waste management at the global level is one of the biggest challenges. A. Saad *et al*. (2022) believed that quality waste management can be a means of reducing the destruction of human health and nature. The increase in population, together with economic growth and development of consumption, is accompanied by an increase in the volume of waste worldwide. The expansion of the world economy, the industrial revolution and cultural development are accompanied by an increase in goods, which in the future also become the main factors in the growth of waste volumes. Accordingly, against the background of climate change, problems with the global accumulation of waste are emerging.

G. Odhiambo (2022) also supported the view that unsystematic and ineffective waste management can lead to the accumulation of garbage and increase the level of environmental pollution. In the future, it is expected to reduce the negative impact on the environment of the poorly developed waste management system. E. Taelman *et al*. (2018) established that it is very difficult to recreate the improvement of waste management, because environmental, economic, social, geographical spheres of activity must be involved in this direction.

Companies that provide waste disposal services are business structures and, accordingly, need marketing activities for development. R. Patel (2023) found that in today's competitive market, it is marketing that plays an important role in shaping the success of a waste disposal company. In accordance with the development of environmental awareness of consumers, the pickiness in choosing waste disposal services is increasing. In addition, a waste management business owner can differentiate their own services and create a brand of reliable and trusted supplier according to the industry. Effectively implemented marketing also helps to increase customer loyalty and retain them. By communicating the value of their services and engaging with existing customers through various marketing channels, a waste disposal company can build strong and long-lasting relationships with them. Accordingly, such measures will allow you to retain the client base and expand the volume of referrals, which in the future will be a major factor in the long-term growth and success of the waste disposal firm (Patel, 2023).

O. Kayode (2022) determined that targeted interaction with customers using mass media (for example, direct mail, television, newspapers and magazines, radio, Internet, billboards, etc.) is carried out at the expense of marketing communications. That is, there is an exchange of information about the products and services of waste disposal organizations between them and the recipients. After all, before positioning the product in the mind of the buyer, it is necessary to first build awareness with the help of an advertising set to such a level that the buyer creates a positive image of both the services themselves and the entire waste disposal company (Kayode, 2022). That is why there is a need to organize effective sales of waste disposal services through the development of marketing communications.

The purpose of the study was to analyze current trends in waste management in Ukraine and to identify directions for improving marketing communications in the context of the optimal waste management model.

METHODS AND MATERIALS

The theory and research methodology are based on the main studies of scientists from Ukraine, the United States of America, the Arab Emirates, Great Britain, Japan, Germany, Spain and Portugal regarding the development of marketing communications in the waste management system. The research used a systematic method to determine the category of "waste management", establish the essence of waste disposal and processing, and determine the main aspects of marketing activities in the context of waste management (Chakraborty *et al*., 2021).

With the help of the analysis method, the current state of waste management in Ukraine was considered, data was systematized regarding the indicators of volumes of waste generated, waste disposed of, waste incinerated, volumes of waste removed to specially designated places and objects, available waste in places of temporary storage of waste at the end year, volumes of waste accumulated during operation, in specially designated places and facilities. Also, during the study of the state of waste management in Ukraine, a structural method was used to determine the share of specific

waste in the total volume. This method was also used to determine the characteristics of the participation of various types of waste.

When the dynamics of waste volumes were determined, the method of mathematical relative analysis was applied, which helped to establish the peculiarities of changes in the percentage value during the studied period of indicators of the volumes of generated waste, disposed waste, incinerated waste, removed waste to specially designated places and objects, existing waste in places of temporary storage of waste at the end of the year, waste accumulated during operation, in specially designated places and facilities. The integrated method provided an opportunity to substantiate the areas of improvement of waste management measures based on marketing communications. With the help of the integrative approach, the main measures for waste disposal and marketing communications were determined in the context of the optimal model of the national partner system of waste management in Ukraine. And the method of mathematical modeling made it possible to establish the peculiarities of the dependence of the supply of primary energy from the source of biofuel and waste on the generation of waste in Ukraine.

The information base was based on articles and research by experts from Coventry University, Beirut Arab University, University of Mississippi and Polytechnic University of Valencia, University of Oxford. Information from the Ministry of Environmental Protection and Natural Resources of Ukraine (2023), European Commission (2018) was also used to identify the features of waste disposal processes. Data from the State Statistics Service of Ukraine (2023) were used as the basis for the analysis of the state of waste management in Ukraine, which made it possible to consider indicators of various types of waste.

RESULTS

In Ukraine, an imperfect waste management system causes soil, water, and air pollution and harms health, because 94% of waste is not processed, but sent to the landfill. That is why it is important to focus on the expansion of recycling activities in terms of their management (Zaklekta & Mochuk, 2021). Processing of waste is considered to be any technological operations based on changing the physical, chemical or biological properties of waste. The purpose of such actions is to prepare waste for its disposal, removal or environmentally safe storage and transportation. That is, processing can be considered a preliminary stage for carrying out further measures to use waste as secondary energy or material resources, or to burn it to obtain electrical or thermal energy. At the same time, in European countries, the main part of waste is subject to secondary processing (Jardosh *et al.*, 2020).

And in Ukraine, these methods of working with waste are at the stage of study, because there is no established industry for processing and disposal of waste in the country. High-quality processing of waste consists in separate collection, that is, it should take place on the basis of their sorting into types exactly at the place of their origin. In Ukraine, the culture of distributed collection of household waste is almost absent among the population. Only episodic implementation of similar systems is observed, which in turn does not bring any benefit. The sector of waste disposal of electronic equipment is important, because it contains substances dangerous for the environment and humans. Used batteries pose the same threat. But in Ukraine, there is still no enterprise that would be aimed at proper processing of waste.

If pay attention to European countries, they process 20-25% of the total volume of municipal waste through incineration (Zaklekta & Mochuk, 2021). In recent years, plastic recycling has become a very relevant issue in the European Union. Accordingly, there is a long-term strategy for the circular recycling of plastics, which will allow the development of concrete actions that extend to national and regional authorities, cities, the plastics industry and all relevant stakeholders, who must commit to decisive and concrete actions (European Commission, 2018).

An example of a successful waste management system is Japan, where about 65% of the total amount of municipal waste is processed by incineration. At the same time, the share of recycled waste increased to 17%, and buried waste decreased to 18%, which is more than two times less than 25 years ago. Recycling in Japan is based on 73% of waste paper and up to 83% of glassware, but the degree of plastic recycling is only 40%, which can be considered insufficiently equal, because the country has a huge total mass of plastic bottles (Zaklekta & Mochuk, 2021).

The field of waste processing in Ukraine is at the stage of formation and is promising from the point of view of investment. An inadequate waste management system in the country causes the loss of millions of tons of valuable resource materials that are in waste and that could potentially be used in economic circulation every year. Nevertheless, Ukraine is trying to implement decisive steps to improve the waste management system, focusing on European principles in this field. Order of the Cabinet of Ministers of Ukraine No. 820-r (2017) has a number of principles that are oriented towards European standards (Fig. 1). This plan consists in the introduction of economic stimulation measures for the implementation of ecologically clean production technologies and the expansion of the direction of processing with the provision of facilities for the processing of various wastes.

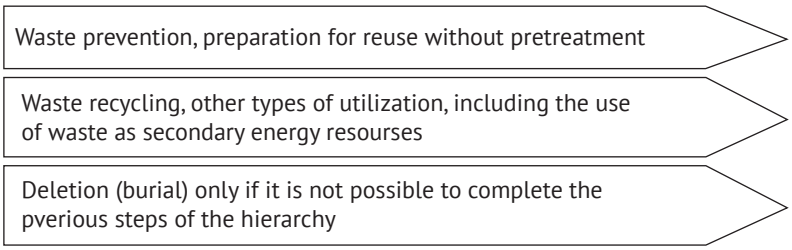

Figure 1. *Principles of National Waste Management Strategy in Ukraine until 2030*
Source: *compiled by the authors*

In connection with the adoption of Law of Ukraine No. 2320-IX (2022), Ukraine started implementation of Directive 2008/98/EC of the European Parliament and of the Council (2008), which is the main factor in establishing new European rules of operation in the direction of waste management. Effective implementation of innovations requires the involvement of responsible business. Today, activities are being carried out in 4 main areas to improve the waste management system in Ukraine. That is, the development of sectoral legislation regarding the effective management of waste from the extractive industry, the introduction in Ukraine of the broad responsibility of the producer himself, the establishment of economic means of stimulating the development of the industry and the increase of the level of administrative responsibility for violations of the adopted rules. The only sure way for the successful functioning of the waste management system is the introduction of waste management reform based on European standards with the use of the latest technologies, which should depend not only on the state, but also on business (Ministry of Environmental Protection and Natural Resources of Ukraine, 2023). In the aspect of researching the waste management system, it is advisable to consider the dynamics of indicators of the volume of generated waste in Ukraine based on the latest data from the country's statistical sources (Table 1).

Table 1. *Dynamics of indicators of volumes of generated waste in Ukraine during 2019-2020, thousand tons*

Volume of generated waste			2019	2020	Growth rate, %
total			553.0	532.0	-3.8
The amount of waste transferred by producers to the side	including	total	258.1	243.8	-5.5
		for disposal	212.1	183.0	-13.7
		to remove	27.6	40.7	47.5
		individuals for use	18.4	20.1	9.2
The amount of exported waste			2.2	0.1	-95.5
The amount of imported waste			3.6	1.5	-58.3
The amount of disposed waste			252.1	228.2	-9.5
The amount of incinerated waste			10.6	10.6	0.0
The amount of waste removed to specially designated places and objects			93.3	103.6	11.0
The amount of available waste in temporary waste storage facilities at the end of the year			128.2	128.3	0.1
The amount of waste accumulated during operation in specially designated places and objects			12305.1	12194.8	-0.9

Source: *compiled by the authors based on State Statistics Service of Ukraine (2023)*

Such trends indicate a low level of development of disposal measures in Ukraine, which is accompanied by the accumulation of large volumes of waste. The statistics shown in Table 1 are presented as of the period before the full-scale invasion of Ukraine, but the dynamics as of 2023 have not changed. That is, despite the reduction of the population of Ukraine due to hostilities and the large number of refugees who left abroad, the proportion still remains relevant in 2023. Therefore, it is rational to consider the peculiarities of waste generation in Ukraine according to types (Table 2).

Table 2. *Dynamics of indicators of volumes of generated waste in Ukraine according to types in 2020, thousand tons*

Type of waste	Volume of generated waste	Volume of disposed waste	Volume of disposed waste	Volume of waste removed to specially designated places and objects	Volume of available waste in temporary waste storage places at the end of the year	Volume of waste accumulated during operation in specially designated places and objects
Total	553.0	252.1	10.6	93.3	128.2	12305.1
Waste acids, alkalis or salts	155.7	95.1	4.9	52.7	4.9	2484.9
Used oils	14.2	15.2	2.2	0.0	6.4	0.5
Chemical waste	16.4	3.2	1.1	8.1	35.2	915.8
Sediment of industrial effluents	24.8	8.1	0.0	1.5	17.7	980.6
Medical and biological waste	0.2	0.0	0.1	0.0	0.1	0.1
Waste of ferrous metals	117.1	18.7	–	0.0	41.8	68.8
Waste of non-ferrous metals	4.6	1.9	–	0.0	1.4	0.0
Mixed waste of ferrous and non-ferrous metals	0.7	0.0	0.0	0.0	0.8	0.3
Rubber waste	1.8	0.0	0.0	0.0	1.6	0.1
Wood waste	1.8	0.1	0.2	0.0	1.4	2.7
Waste containing polychlorodiphenyls	0.3	–	0.1	–	0.0	0.1
Waste of plant origin	1.1	0.9	0.1	–	0.0	–
Animal excrement, urine and manure	20.1	13.6	–	–	0.3	–
Household and similar waste	0.1	–	–	–	0.0	0.3
Mixed and undifferentiated materials	73.5	58.5	0.5	8.8	4.9	183.4
Sorting remnants	0.1	–	–	–	0.2	–
Normal sediment	6.3	3.4	–	0.3	0.6	160.9
Other mineral waste	57.0	2.7	0.0	0.6	2.3	6753.6
Combustion waste	16.5	1.5	0.0	9.7	0.7	380.0
Solidified, stabilized or vitrified waste; mineral waste generated after processing	9.9	–	0.3	9.5	0.1	299.1

Source: *compiled by the authors based on State Statistics Service of Ukraine (2023)*

Accordingly, such a composition of waste in Ukraine in 2020 indicates the need to develop measures aimed at improving the waste management system. In the course of further research, the structure of the most important types of waste according to the generation in 2020 was considered (Fig. 2).

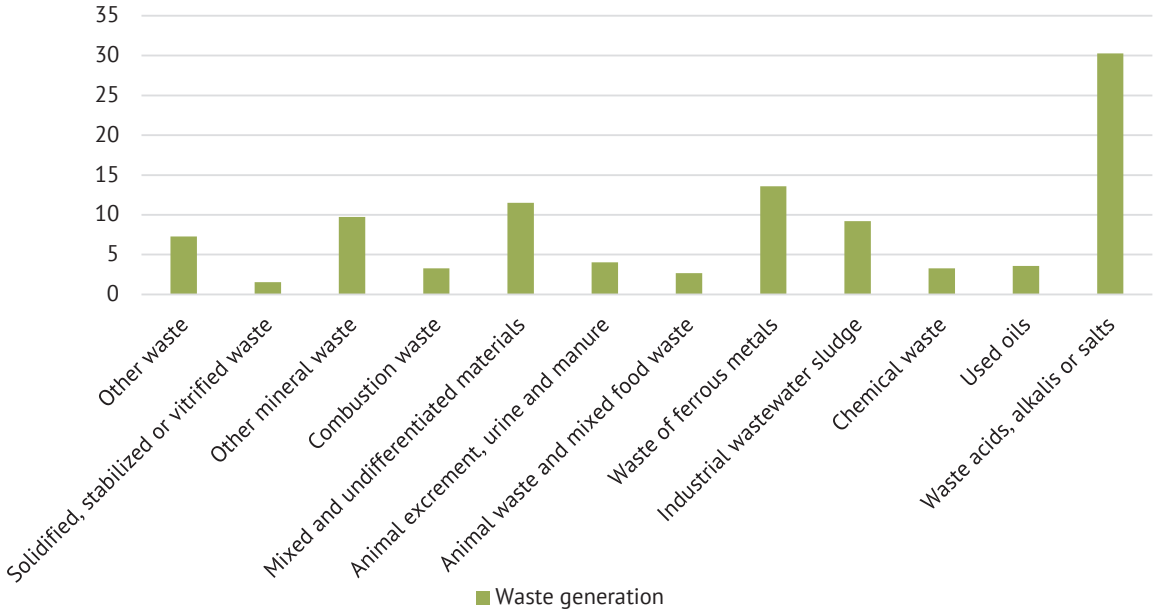

Figure 2. *The structure of generated waste in 2020, %*
Source: *compiled by the authors based on State Statistics Service of Ukraine (2023)*

It can be seen from Figure 2 that among the volumes of generated waste in 2020, the highest volumes were waste of acids, alkalis or salts, because their share in the total volume was 30.26%. At the same time, ferrous metal waste in the structure of generated waste accounted for 13.57%, and mixed and undifferentiated materials together with other mineral waste accounted for 11.50%. Also, in the structure of generated waste, other mineral waste occupied 9.74%, and industrial waste sludge – 9.21%. Chemical waste (3.29%), used oil (3.57%), combustion waste (3.27%), animal excrement, urine and manure (4.04%), waste of animal origin (2.69%) were characterized by somewhat lower shares in the structure of generated waste in 2020. and solidified, stabilized or vitrified waste (1.56%). Other waste in the structure of generated waste occupied 7.29%. In the course of further research, it is advisable to establish the structure of the volumes of waste accumulated during operation in specially designated places and objects (Fig. 3).

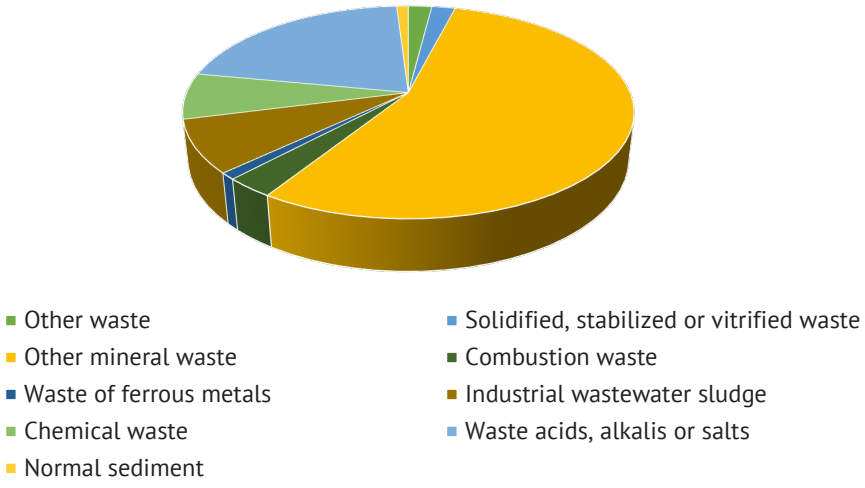

Figure 3. *Structure of volumes of waste accumulated during operation in specially designated places and facilities in 2020, %*
Source: *compiled by the authors based on State Statistics Service of Ukraine (2023)*

It can be seen from Figure 3 that in the structure of the volume of waste accumulated during operation, in specially designated places and facilities in 2020, the highest share was occupied by other mineral waste. Also, the waste of acids, alkalis or salts had a rather heavy specific weight in relation to the volumes of

waste accumulated during operation in specially designated places and objects. At the same time, chemical waste and sediment from industrial effluents each accounted for less than a tenth of the total volume of accumulated waste. By the end of 2020, ferrous metal waste, ordinary sludge, combustion waste, solidified, stabilized or vitrified waste, mineral waste generated after processing and other waste accounted for a relatively small percentage of the accumulated waste in Ukraine.

Thus, the considered trends of the latest dynamics and structure of the features of the waste management system made it possible to establish that measures for the disposal of the following waste need development and improvement:

- waste of acids, alkalis or salts;
- other mineral waste;
- chemical waste;
- sludge from industrial effluents;
- waste of ferrous metals;
- mixed and undifferentiated materials.

Further, the peculiarities of waste generation by source were considered (Table 3).

Table 3. *Dynamics of generated waste in Ukraine by sources for 1995-2020, thousand tons*

A total of thousands of tons of waste was generated	1995	2000	2005	2010	2015	2020
	176400.2	184192.4	231189.5	422549.9	312267.6	462373.5
including						
Agriculture, forestry and fisheries	642.2	1251.3	2593.0	8304.5	8736.8	5315.4
Mining and quarrying	-	-	161817.6	347442.3	257861.9	391077.9
Processing industry	-	-	54800.8	47676.5	31000.5	52311.0
Supply of electricity, gas, steam and air conditioning	12817.7	10066.1	8104.7	8636.4	6597.5	5333.7
Construction	54.8	19.1	198.7	326.7	376.2	14.5
Other types of economic activity	28925.4	1025.6	3674.7	3795.8	1641.4	2371.3
Volume of waste collection from households	-	-	-	6367.7	6053.3	5949.7
GDP (gross domestic product) at purchasing power parity (PPP) in constant 2011 prices	260.6	235.9	341.3	358.9	319.8	-
The amount of generated waste from economic activity per unit of GDP at purchasing power parity in constant prices of 2011	676.9	780.8	677.4	1159.6	957.5	-
Volume of waste collection from households per person	-	-	-	138.7	141.4	142.7

Source: *compiled by the authors based on State Statistics Service of Ukraine (2023)*

During 1995-2020, there is an increase in the amount of generated waste, which is accompanied by an increase in the amount of waste from agriculture, forestry and fishing, the mining industry and the development of quarries. Although at the same time, the volumes of generated waste from construction, processing industry, supply of electricity, gas, steam and air conditioning, other types of economic activity and from households decreased. Although there is an increase in the volume of waste collection from households per person. According to the identified most significant generated and accumulated waste in Ukraine, it is advisable to propose the following measures for disposal and marketing communications in the aspect of improving the country's waste management system (Table 4).

Table 4. *Measures for waste disposal and marketing communications in the context of the optimal model of the national pattern system of waste management in Ukraine*

Types of the most significant accumulated and generated waste	Necessary disposal measures	Marketing measures
Acid, alkali or salt waste and chemical waste	Removal of substances in any form, including by special transport; ensuring complete safety during waste collection and transportation; carrying out the correct disposal of waste by means of its preliminary treatment or processing; ensuring neutralization of the negative impact of waste on the environment.	Implementation of measures to stimulate the state of these enterprises. Informational support for waste processing through mass media Creation of social videos about the need for proper disposal of this waste

Table 4, Continued

Types of the most significant accumulated and generated waste	Necessary disposal measures	Marketing measures
Other mineral waste and sludge from industrial effluents	Implementation of comprehensive recycling measures	Establishing relationships between producers and consumers of secondary products
Waste of ferrous metals	Dismantling of structures and collection of metal waste; transportation of waste to a processing enterprise; inspection of metal waste (including dosimetric waste); final waste control; transformation of waste into finished raw products or commercial metal scrap, ready to be used for metal smelting	Informing consumers of services and potential buyers of secondary raw materials regarding the full range of services for the collection, removal and further utilization of metal waste and the availability of the appropriate license
Mixed and undifferentiated materials	The activity is aimed at using the energy potential of waste	Creation of a marketing complex around secondary products. Use of secondary products in energy efficiency

Source: *compiled by the authors based on M.C. Xenya et al. (2020), K. Thibuy et al. (2020), Ch. Mbama et al. (2023)*

It is important to carry out marketing activities in the direction of developing advertisements for the use of secondary raw materials in energy. This practice of converting waste into energy is quite relevant and effective in Europe and can be an example for Ukraine (Cameron, 2015). In Ukraine, the practice of involving consumers in the process of manufacturing secondary products is gaining momentum. Or the use of waste for the formation of the interior, means of decoration or improvised things is observed (Zaklekta & Mochuk, 2021). To develop a waste disposal business, it is necessary to carry out marketing communication of the following structure (Fig. 4).

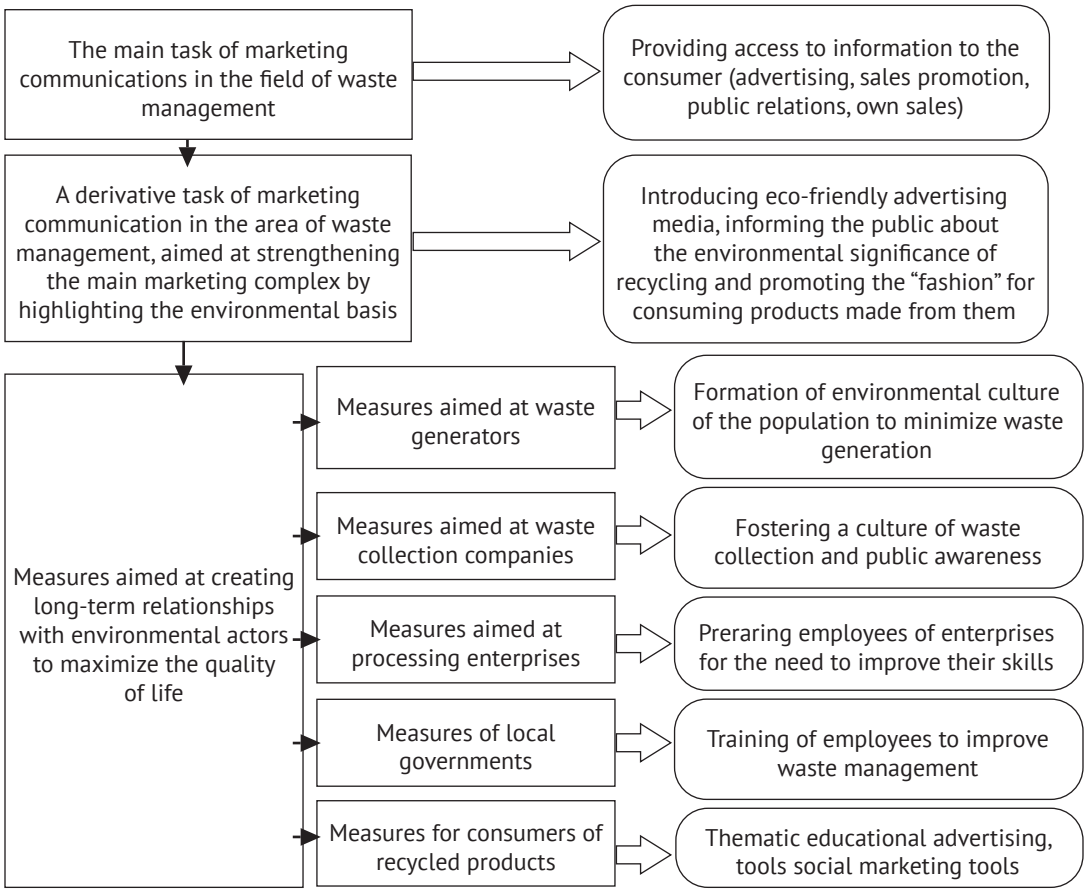

Figure 4. *The structure of marketing communications for waste management business in Ukraine*
Source: *compiled by the authors*

The main task of marketing communications in the aspect of running a waste management business in Ukraine should be the implementation of effective measures to inform the country's population about the importance and necessity of this direction. It is important to develop ecological media for advertising, to provide accessible information about the ecological importance of proper waste disposal and introducing the habit of consuming secondary products. In addition, at the stage of waste generation, it is important to carry out marketing communications in the direction of building a culture of citizens and enterprises regarding environmental measures to minimize waste (Jadli & Hain, 2020). At the same time, processing enterprises are recommended to increase the level of qualification and awareness of employees with the help of marketing communications, and self-government bodies also need to improve the awareness of employees regarding waste management.

It is also important to develop measures for consumers of secondary raw materials using thematic educational advertising and social marketing tools. This structure of marketing communications for running a waste management business in Ukraine will bring recycling to a new level and increase its efficiency. It is expedient to pay considerable attention to indicators of the volume of generated waste of potential secondary raw materials of Ukraine (Table 5).

Table 5. *Dynamics of indicators of volumes of generated waste of potential secondary raw materials of Ukraine according to types in 2020, thousand tons*

Waste	Volume of waste generated	Volume of waste transferred by manufacturers	Volume of waste disposed	Volume of incinerated waste	Volume of waste removed to specially designated places and objects	Volume of available waste in temporary waste storage places at the end of the year	Volume of waste accumulated during operation in specially designated places and objects
Waste of non-ferrous metals	24.3	25.9	5.4	0.0	0.0	12.2	4.0
Mixed waste of ferrous and non-ferrous metals	10.3	9.8	0.0	0.0	0.0	3.4	1.7
Glass waste	21.0	15.8	7.1	0.0	0.4	113.3	128.3
Paper and cardboard waste	140.8	102.9	0.0	0.3	4.3	8.3	228.2
Plastic waste	40.8	31.2	15.1	0.3	3.2	10.7	110.4
Textile waste	21.9	21.0	0.9	0.1	1.1	1.0	22.2
Unsuitable equipment	5.0	4.2	0.8	0.1	0.2	1.1	1.8
Unsuitable vehicles	1.0	1.0	0.0	–	–	0.7	–
Accumulators and battery waste	4.2	3.6	29.0	–	0.0	4.0	0.0
Animal waste and mixed food waste	405.4	177.9	203.4	4.5	1.9	3.2	45.1

Source: *compiled by the authors based on State Statistics Service of Ukraine (2023)*

It can be seen from Table 5 that the volumes of generated waste of potential secondary raw materials of Ukraine in accordance with the types in 2020 are mostly transferred to producers on the side, accordingly, the volumes of waste accumulated during operation in specially designated places and objects are insignificant. Non-ferrous metal waste and mixed ferrous and non-ferrous metal waste, unusable equipment and unusable vehicles have the greatest demand for further production. Waste batteries and batteries, animal waste and mixed food waste are being disposed of quite actively. Compared to other methods of waste management of potential secondary raw materials, incineration is practically not carried out, i.e., a low proportion of waste, which is unsuitable for further processing, is incinerated. At the same time, by the end of 2020, glass waste is stored in

significant quantities for further processing. The volume of waste accumulated during operation in specially designated places and objects is characterized by a significant amount of plastic waste, glass waste, paper and cardboard waste, and textile waste. Accordingly, it is advisable to single out a number of marketing measures that should be aimed at promoting waste as a potential secondary raw material at the national and local levels (Fig. 5).

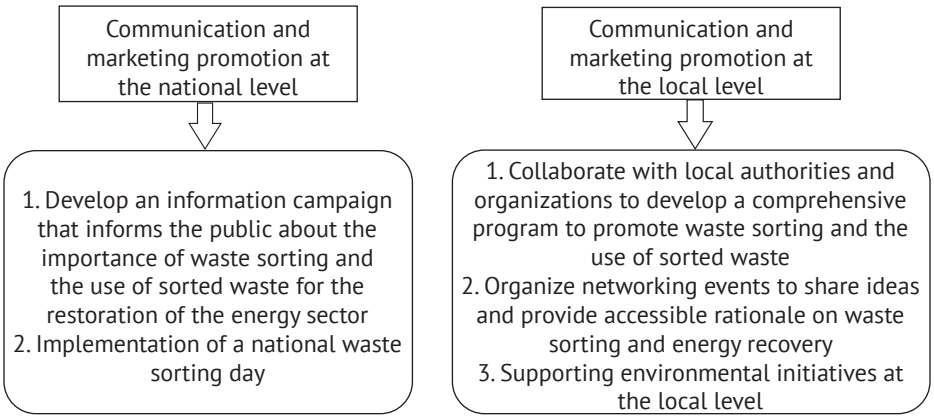

Figure 5. *Marketing communications are aimed at promoting waste as a potential secondary raw material at the national and local levels*

Source: *compiled by the authors*

State authorities are recommended, in addition to developing an information campaign that informs the public about the importance of waste sorting and the use of sorted waste to restore the energy complex, it would be advisable to implement, for example, National Waste Sorting Day. It is important to spend this day simultaneously with various activities and contests that will help attract public attention to this topic. At the local level, it is expedient to hold, for example, seminar events, lobbies, presentations and discussions for the exchange of ideas and accessible reasoning about waste sorting and restoration of the energy complex. At the same time, it is important to have environmental initiatives, that is, to create sorting points, to register in energy complex recovery programs, to promote social projects that promote waste sorting (Khan & Ali, 2021).

Implementation of high-quality waste sorting will help improve the country's energy balance, which is quite relevant at the stage of martial law. If consider the dynamics of the supply of primary energy from the source of biofuel and waste together with the dynamics of the generation of waste itself, the tendency to increase both indicators can be followed (Fig. 6).

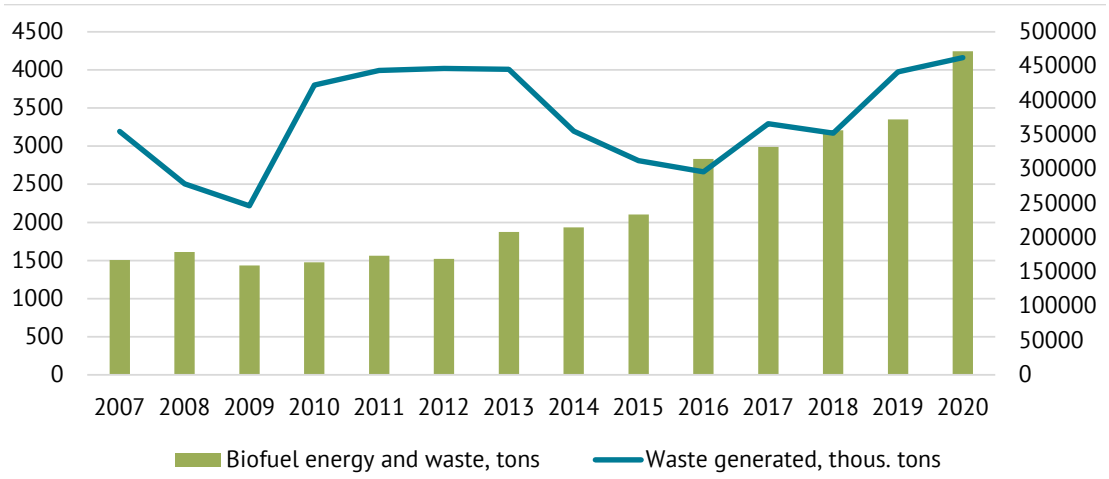

Figure 6. *Dynamics of primary energy supply from biofuel and waste sources and waste generation in Ukraine, during 2007-2020*

Source: *compiled by the authors based on State Statistics Service of Ukraine (2023)*

The construction of a one-factor regression helped to consider the dependence of the supply of primary energy from the source of biofuel and waste on the generation of waste in Ukraine (Table 6).

Table 6. *Results of the construction of the dependence of the supply of primary energy from the source of biofuel and waste on the generation of waste in Ukraine*

Regression statistics						
Multiple R	0.25					
R-square	0.06					
Normalized K-square	-0.02					
Standard error	904.77					
Observations	14.00					
Variance analysis						
	df	SS	MS	F	Significance F	
Regression	1.00	650709.55	650709.55	0.79	0.39	
Remainder	12.00	9823231.67	818602.64	-	-	
Total	13.00	10473941.21	-	-	-	
	Coefficients	Standard error	*t*-statistic	*P*-value	Low 95%	Top 95%
Y-crossover	1094.08	1330.27	0.82	0.43	-1804.32	3992.49
The variable X 1	0.0031	0.00	0.89	0.39	0.00	0.01

Source: *compiled by the authors*

From Table 6, it can be determined that there is a direct and weak relationship between the supply of primary energy from a biofuel source and waste from waste generation in Ukraine. At the same time, the increase in the amount of waste in the country per unit is accompanied by an increase in the energy of biofuel and waste by 0.0031 tons. That is, there is a connection between waste and the generation of energy from sources of secondary raw materials. Accordingly, an established waste sorting system will help introduce potential waste reduction and increased availability of recycled materials for energy production, as well as improved environmental and public health outcomes.

DISCUSSION

For Ukraine, the issue of marketing communications in the waste management system is quite new and poorly researched, because the waste disposal structure itself is imperfect. An example for the development and implementation of a waste management system is the peculiarities of disposal measures in Europe. After all, for example, when in Ukraine there is only a slight competition among companies in this direction, then in Europe companies are already being created that focus on minimizing the amount of waste.

P. Munten & J. Vanhamme (2023) note that a serious global environmental problem is both the increase in the amount of waste and the demand for its disposal. Such trends contribute to the development of sustainable strategies for waste management. The authors prefer long-term solutions in the aspect of waste management, that is, they recommend optimizing the average life of consumer goods, rather than resorting to recycling and re-production, in order to prevent the generation of unnecessary waste. It is their repair that can increase the service life of goods, which is a viable long-term solution. Although relative to sustainable waste management, the repair aspect is rarely explored. To reduce the amount of waste, managers are recommended to strengthen and improve their own waste management processes and to encourage the repair of goods. The authors of this article agree with the conclusions obtained as a result of the study of P. Munten & J. Vanhamme (2023) and believe that by combining these two works, it is possible to develop a comprehensive waste management strategy that will take into account current problems and long-term goals of sustainable waste management.

Sh. Vishwakarma *et al.* (2022) conducted research to review the characteristics of e-waste generation and identify the main aspects of its management according to the various challenges and opportunities associated with the sector of sustainable e-waste management. In order to reduce the level of e-waste problems, the researchers developed and implemented a "use case diagram", which consists of interaction between people of different positions and roles with the e-waste management processes themselves. The diagram is built on the interaction between users and the system. The sector of information and computer technologies is one of the main factors influencing the country's economic growth, because its development is accompanied by an increase in GDP, an increase in the number of jobs and an

increase in foreign currency income. At the same time, electronic waste management itself is a significant risk for the technical world. The authors determined that several policies of a corporate nature and stakeholder management strategies have been formed by the relevant industries in order to combat the problems of e-waste. Accordingly, the study recommends that the IT sector develop a well-managed e-waste management system through stakeholder engagement. The authors determined that under the condition of developing a comprehensive strategy for the management of electronic waste, which takes into account technical, economic, ecological and socio-cultural aspects, it is possible to capitalize their transformation into wealth. In summary, the authors add that various initiatives have been launched around the world to address the problem of e-waste (Vishwakarma *et al.*, 2022). Nevertheless, the authors of this article can agree that in recent years, with the development of technologies, the issue of electronic waste management has intensified.

D.J.C. da Silva *et al.* (2022) in their study developed an optimal model of waste management in the field of construction based on the implementation of recycling and subsequent reuse of aggregates. In order to generate empirical evidence, the authors conducted a case study in the south of Brazil. They explained the need for such a model by the fact that with the increase in cities in the world, construction is gaining momentum, and accordingly, the amount of waste is increasing. Accordingly, the study showed that there are a diverse number of alternative options for construction waste through the use of a waste recycling method. The main goal of the developed model is the improvement of the solid waste management system. The authors detailed the roles of each participant in the construction waste management model in accordance with the coordination of municipal bodies. At the same time, the developed model does not take into account territorial features, and, accordingly, can be applied in other regions, companies and industries (da Silva *et al.*, 2022). Researchers see the partnership between various participants as the basis of successful waste processing. According to the authors of the current article, although this model does not consider marketing aspects, it allows building a simplified system for managing large volumes of waste.

M. Tanveer *et al.* (2022) carried out a large-scale study of the peculiarities of waste management in the conditions of a cyclical economy and the development of green technologies. The authors considered 1,118 scientific articles covering the period from 2000 to 2021. The study covered topics related to the specifics of plastic, electronic and construction waste management. Aspects of biological waste management were also determined and the impact of the life cycle on the environment was established. The authors established that in developed countries the waste management system is established and in general allows them to improve not only the ecological environment, but also their global system in the direction of a sustainable environment. Effective monitoring of human activity in the direction of impact on the environment contributes to such trends. Researchers identified low effective waste management in developing and underdeveloped countries. Thus, the researchers established that the movement towards effective implementation of waste management in an intelligent system is accompanied by an increase in the environmental sustainability of the country (Tanveer *et al.*, 2022). The authors of this study agree that circular economy and green technologies should be present in the chain of waste management in Ukraine, but M. Tanveer *et al.* (2022) do not provide specific recommendations, which makes it difficult to improve this system.

C.-A. Vargas-Terranova *et al.* (2022) conducted research on the optimal design of waste management systems in low-income municipalities. The developed model allows low-income organizations in the aspect of waste management to make calculations based on two scenarios that allow integrating the assessment of socio-cultural dynamics. In addition, the proposed model includes the analysis of other variables that are mostly considered in solid waste management schemes. That is, it takes into account the reduction of the carbon impact based on the transportation of waste to be processed and through the formation of leachates and greenhouse gases, which occurs when the number of associated processors and sampling routes increases (Vargas-Terranova *et al.*, 2022). The authors of this article note that the results obtained using the constructed C.-A. Vargas-Terranova *et al.* (2022) models, which differ from previous results based on the linear economy approach. It is also impossible to assess the optimality of the described model, because the researchers did not take into account the economic aspect.

The waste management system in Ukraine is at the initial stage of development compared to other European countries. Despite this, there has been some progress in the implementation of effective waste management, in particular through the development of sectoral legislation, the establishment of economic incentives and an increase in the level of administrative responsibility. However, there is a need for further development and improvement of measures for disposal of various types of waste, in particular chemical, construction, electronic and other, as well as reduction of accumulated waste during operation.

CONCLUSIONS

Therefore, the analysis of the theoretical aspects of the features of the waste management system in Ukraine

showed that waste disposal is at an initial stage of development compared to other European countries. Today, the development of sectoral legislation regarding the effective management of waste from the mining industry is just beginning. Wide responsibility of the producer himself is being introduced in Ukraine, and economic means of stimulating the development of the industry are being established. At the same time, measures are being implemented to increase the level of administrative responsibility for violations of the adopted rules. The introduction of waste management reform on the basis of European standards with the use of the latest technologies, which should depend not only on the state, but also on business, is considered the only true way for the successful functioning of the waste management system. The waste analysis carried out showed that there is an increase in the amount of waste transferred by producers to the party for removal and use, which is accompanied by a decrease in the amount of waste disposal of this direction of management. At the same time, the amount of waste accumulated during operation in specially designated places and objects is quite large, which indicates a low level of development of disposal measures in Ukraine. The conducted analysis of trends in the latest dynamics and structure of the features of the waste management system allowed us to determine the need for development and improvement of measures for the disposal of acid, alkali or salt waste, other mineral waste, chemical waste, industrial waste sludge, ferrous metal waste and mixed and undifferentiated materials. The waste disposal measures identified in the study will make it possible to organize comprehensive recycling measures, to reproduce the use of the energy potential of waste. At the same time, the proposed marketing measures will help to implement state incentives for recycling enterprises, provide informational support for waste processing through mass media, establish relationships between producers and consumers of secondary products, create a marketing complex around secondary products and recreate the use of secondary products in energy efficiency. Also, the proposed system of marketing communications for conducting waste management business in Ukraine will provide an opportunity to increase the efficiency of disposal and bring it to a new level with the help of environmental advertising events. It has been established that an established waste sorting system can contribute to the reduction of waste and should be accompanied by an increase in the availability of recycled materials for energy production, which will collectively help improve the country's environment.

The conducted research on the types of waste and secondary raw materials was carried out with the aim of building high-quality marketing communication, on the basis of which measures are planned for a positive impact on society. Further research should be based on the development of new methods of evaluating the efficiency of waste disposal based on their use as energy products of the zones and should be focused on the introduction of measures to evaluate the effectiveness of the proposed marketing measures aimed at attracting investors to the waste disposal business.

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CONFLICT OF INTEREST

None.

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Маркетингова комунікація в контексті оптимальної моделі національного патерну системи управління відходами в Україні

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Анотація. Питання стосовно раціонального управління відходами в Україні стоїть доволі гостро. Система знаходиться у стані занепаду, адже близько 94 % відходів потрапляють на сміттєзвалища та тим самим негативно впливають на навколишнє середовище. Саме тому питання побудови досконалої системи управління та застосування при цьому маркетингових комунікацій в Україні є досить актуальним, адже належне управління відходами за допомогою маркетингових заходів дозволить не тільки зберегти навколишнє середовище, а й залучити вторинну сировину в енергетичне чи подальше виробництво. Метою даної роботи було дослідження та узагальнення аспектів маркетингових комунікацій в контексті оптимальної моделі національного патерну системи управління відходами в Україні. У дослідженні були використані системний метод, метод аналізу та комплексний й інтегративний методи. Було визначено, що рівень обсягів утворених та накопичених відходів в Україні є досить високим. Встановлено, що необхідно розвивати та удосконалювати заходи з утилізації саме відходів кислот, лугів чи солей, інших мінеральних та хімічних відходів, осадів промислових стоків, відходів чорних металів та змішаних та недиференційованих матеріалів. Визначено необхідні заходи з утилізації відходів, які у свою чергу мають надати можливість організувати проведення комплексних заходів з переробки відходів та забезпечать використання їх енергетичного потенціалу. Встановлені у дослідженні маркетингові комунікації допоможуть здійснити впровадження заходів зі стимулювання з боку держави підприємств з утилізації, провести налагодження взаємозв'язків між виробниками та споживачами вторинної продукції, надати інформаційну підтримку переробки відходів через ЗМІ, здійснити створення маркетингового комплексу навколо вторинної продукції та відтворити використання вторинної продукції в енергоефективності. Рекомендована структура маркетингових комунікацій для ведення бізнесу з управління відходами в Україні дозволить вивести на новий рівень утилізацію та підвищити її ефективність. Практична значимість дослідження полягає в тому, що визначені заходи з утилізації відходів та супровідних маркетингових комунікацій можуть бути використані в Україні з метою підвищення результативності системи управління відходами

Ключові слова: маркетингова комунікація; управління відходами; реклама; тренди; трансформація суспільних цінностей

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The impact of a warm, dry climate on sheep

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Abstract. Sheep breeds originating from arid and semi-arid regions are known for their ability to adapt to the rural environment, climatic fluctuations, and lack of resources. Water scarcity, which is often combined with heat stress, is an urgent problem for sheep farmers in arid regions, which these animals face, causing physical disorders and affecting animal productivity. The purpose of this work is to determine the impact of this problem on this branch of animal husbandry and to find steps to reduce the negative impact of high temperatures and humidity. In the course of writing this article, theoretical general scientific research methods and data analysis from universities in the USA, Brazil, Kazakhstan, Australia, Turkey and Mongolia were used. After analysing the studies and summarising them, the article also provides information on the peculiarities of zoning and climate of Ukraine, which affects the sheep industry. The degree of influence of high wind humidity and temperature on the emergence of scours in sheep is considered. It was found that heat stress is the most important climatic factor that negatively affects livestock production and sometimes even threatens the survival of animals. Among the climatic components that can cause stress on different sheep qualities are ambient temperature, humidity wind movement, photoperiod, solar radiation, wind speed, etc., of which ambient temperature is the most important variable. Although the influence of the season can be significant, the following general responses to drought and heat stress can be identified using animal behavioural data Reduced feed intake and weight loss, increased cooling by evaporation through respiration, production of small amounts of highly concentrated urine, haemoconcentration, high blood salinity and immunosuppression. Improving the heat state of animals by physical, physiological and/or nutritional methods, in addition to following good management practices at the appropriate time, can help animals exposed to heat stress to realise their genetic potential in hot and arid regions, which is of practical value

Keywords: warm zone; productivity; ambient temperature; fat tail; natural and agricultural zoning of the territory

INTRODUCTION

Livestock farms and enterprises of the arid region make a living from sheep breeding, which has served as a constant source of livelihood for people living in arid and semi-arid areas since ancient times. Sheep can be fed low-quality biomass during periods of raw material shortage, and they are able to convert it into brown products such as milk, meat and wool. In the current perspective of global climate change, it is very important to understand the impact of environmental changes on the organism, as well as the adaptive mechanisms in their arsenal to combat them. The semi-arid environment is one of the main agro-ecological zones of the tropics, and within the borders of Ukraine it corresponds to the Steppe zone. There is a direct relationship between agro-climatic conditions, population density, agricultural systems and animal husbandry (Antonenko *et al.*, 2019).

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Global temperatures are expected to rise by more than 1.5°C, and drought will become one of the most common and severe disasters affecting humans. The fact that the average annual temperatures on the planet are increasing was again stated in the latest report of the Intergovernmental Panel on Climate Change AR6 Climate Change 2021 (Ivanyuta & Yakushenko, 2022). And this means that the topic of heat loss in all food animals is becoming more and more relevant. It can be detected by several characteristic signs – feeding behavior changes, the animal breathes more often, secretes more mucus, productivity drops. Heat stress level indicators are measured on the THI scale (temperature-humidity index), the heat stress index (Heat stress…, 2019) is also used.

Morphological adaptations are observed even in sheep adapted to arid and semi-arid regions. The type of fleece and the color help protect against heat and minimize water loss due to evaporation. Native breeds in arid and semi-arid areas, such as Marwari, Omani, Barbarin and Awachi, all have carpet-type wool. This type of wool, compared to denser types of wool, appears to provide protection from solar radiation while providing effective evaporative cooling of the skin at night (Bonin *et al.*, 2023).

For comparison, sheep of the woolly fleece type are less thermally resistant in hot conditions compared to their woolly counterparts. In tropical conditions of high temperature and high humidity, scientists came to the conclusion that sheep of the fleece type were better adapted than wool breeds. In addition, light fleece provides better reflection of solar radiation, thus keeping the skin below cooler compared to darker fleece (McManus *et al.*, 2020).

An anatomically adapted characteristic of heavy breeds of sheep from arid and semi-arid regions is a fat tail. Such external localization of fat allows for better heat dissipation from the rest of the body, since the body is less insulated by fatty tissue. In addition, the fat stored in the tail is a store of energy that can be mobilized during the lack of food. The concept of tail fat as a metabolic water reserve has been discredited, and it is now believed that its primary role is to provide energy when dietary energy intake is inadequate, leading to some metabolic formation of water, which can partially help to fill the animal's water needs. The contribution of water intake, which may be derived from metabolic sources, has been found to be approximately 8.5% in Yanka sheep, while others have reported losses of up to 15% in sheep in general. This effect is influenced by the level of dependence on the catabolic mobilization of fat and protein body tissue (Silva *et al.*, 2023).

In Ukraine, namely in the Steppe zone, the topic of climate influence is more relevant than ever. It is already possible to observe such phenomena as extremely high air temperature, increased humidity and, in addition, the impoverishment of pastures for feeding flocks. All this creates problems that do not improve the livestock industry, and may even lead to its decline: climate warming, overgrazing, and land reclamation lead to the degradation of pastures, which, in turn, reduces the scale of feed and walking areas and the yield of agricultural crops. cultures Further, the expansion of the scale of animal husbandry and the scale of reclamation is predicted, which will inevitably lead to the acceleration of pasture degradation and the risk of desertification (Li *et al.*, 2023).

In this article, the works of Ukrainian, Turkish, Mongolian, Australian and Brazilian researchers in the field of sheep breeding, as well as the work of scientists from the USA and Kazakhstan, were studied in order to study the impact of heat stress and water shortage on sheep, as well as ways to make life easier and animals to realize their potential thanks to adherence to certain methods and diets. It was planned to present some methods of work of foreign scientists in arid climate to managers and employees of sheep farms in Mykolaiv and Kherson regions.

MATERIALS AND METHODS

For this study, several general scientific methods were chosen, such as description (from empirical), analysis, synthesis, abstraction, generalization, explanation (from theoretical), as well as a system method.

The advantage of the first is that empirical methods are applied at the stage of data and information collection, which means that they are easy to implement and can be applied in any direction. The disadvantage is the lack of practical verification of the collected material. The convenience of the methods of analysis, synthesis and generalization lies in the fact that, first, a large amount of unsystematized information can be studied by dividing it into separate elements, and then, after choosing the necessary fragments, combine them into a whole logical conclusion. There are no disadvantages, since these are basic methods without which no theoretical or practical work is possible. The method of abstraction was chosen due to the possibility of using transitions from specific elements to general concepts and laws of development. It is used everywhere in scientific research, which is also an advantage. Explanation, as a method, is taken to describe cause-and-effect relationships, for example, what will happen to the Steppe zone under the influence of global warming. The disadvantage is the difficulty of explaining some aspects of the studied phenomena and whether they are at all related to each other. The last used system method has the advantage of being able to consider the animal as a model in the system, which allows you to imagine and explore the connections of

sheep with nature, man, technology, ecology and the biosphere in general.

Among the materials and sources, in addition to articles, information on the natural and agricultural zoning of the territory of Ukraine, created by the BioModel Group (n.d.) — a group of experts in biogeoinformatics, spatial modeling of biodiversity using GIS (geoinformation) technologies, and Earth remote sensing data, was used.

According to the scheme of natural and all-purpose zoning of the territory of Ukraine, five natural and all-purpose zones (Polissya, Forest Steppe, Steppe, Steppe Dry, and Dry Steppe) and two mountain o blacti (Carpathian and Crimean) (Fig. 1).

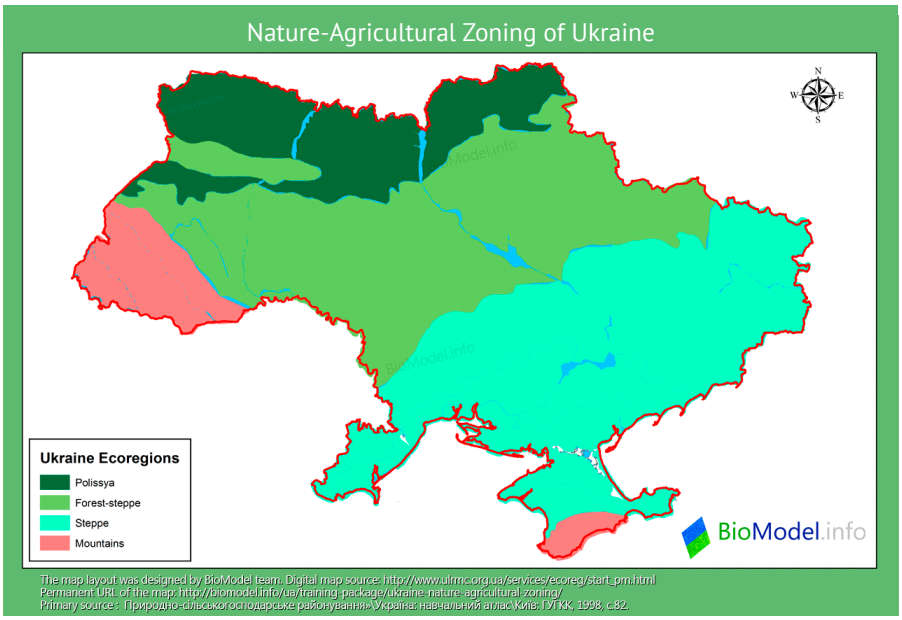

Figure 1. *Scheme of natural and agricultural zoning of the territory of Ukraine*
Source: *BioModel.info (n.d.)*

The territory of the Mykolaiv and Kherson regions is located in the South-Buzka-Ingul district of the Right Bank province of the Steppe natural resource zone. The climate is characterized by the accumulation of continentality, a decrease in the influence of Atlantic air masses and an increase in the role of continental easterlies, a shorter frost-free period.

Average monthly temperatures in July fluctuate between +23.5-34.5°C, and in January – 3.0-5.0°C. The frost-free period lasts 185-200 days, the vegetation period lasts 210-215 days. The annual sum of active temperatures is 3,000-3,200°C. 425-450 mm of precipitation falls per year. The winter is short and with little snow, the average height of the snow cover is 10 cm (Konishchuk & Yehorova, 2018).

Animals can adapt to a hot climate, but the corresponding mechanisms are useful for survival, but harmful for the productive and reproductive system. The temperature-humidity index (THI) is a measure of the combined effect of temperature and relative humidity of the animal's microenvironment. It is a scientifically proven tool for assessing the potential risk of heat stroke in animals. According to the recommendations, a THI with a value less than 68 indicates the absence of heat loss, and a THI in the range of 80-89 determines a loss from moderate to severe. Values of 90 and higher constitute a complete heat loss, which has irreversible consequences for animals, and often fatal ones (Popov & Shish, 2022).

The temperature-humidity index (THI) is calculated using the Kibler formula:

$$\mathrm{THI} = 0.8 \cdot \mathrm{TV}I + \left(\frac{RAH}{100} \cdot (TSE - 14.4)\right) + 46.4,$$

where TSE (T) — temperature of the surrounding environment, °C; RAH (W) — relative air humidity, %.

RESULTS

The effect of heat stress on animals. The mouth, body weight and physiological productivity of the animal depends on hyperthermia. The main means of cooling the body of small ruminants (endothermy, homeothermy, tachymetabolism, heat conduction, convection) are less effective when the temperature of the surrounding environment increases, animals rely more on evaporation non-cooling in the form of sweating and breathing. An increase in air temperature, a temperature-humidity index, and an increase in rectal temperature above the critical level are associated with a decrease in dry matter consumption. Strec suppresses the speed of the mouth on the camphor due to a decrease in feed consumption, as well as due to the effect on digestion and metabolism (Kushnerenko *et al.*, 2019).

Animals that find themselves in conditions of heat stress have several coping mechanisms. They help animals survive the heat, but have a very negative effect on their productivity. The consequences differ greatly for each species of animal and each species within the same species. Each object has a different ability to recover from thermal shock. Therefore, to combat heat stroke, it is necessary to select special methods, taking into account the peculiarities of each animal. Electrolyte balance and osmoregulation are important mechanisms that should be taken into account during heat stroke. They can be controlled with the help of nutrition and appropriate feed additives (Nezhlukchenko *et al.*, 2019).

As part of research at Georgia State University, humidity and air temperature were measured every 30 minutes during the summer in arid regions. It appears that in a quarter of all summer days, the THI index exceeds the mark of 80. This is a high indicator that portends problems for the health of livestock and for the economic stability of the entire livestock enterprise (Fig. 2).

Temperature and humidity index																		
THI		Relative air humidity, %																
		20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Temperature, °C	16	60	60	60	60	60	60	60	60	60	60	60	60	60	61	61	61	61
	17	61	61	61	61	61	61	61	61	62	62	62	62	62	62	62	62	63
	18	62	62	62	62	62	62	62	63	63	63	63	64	64	64	64	64	64
	19	63	63	63	63	63	64	64	64	64	65	65	65	65	66	66	66	66
	20	64	64	64	64	65	65	65	65	66	66	66	67	67	67	67	68	68
	21	65	65	65	66	66	66	67	67	67	67	68	68	68	69	69	69	70
	22	66	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72
	23	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	73
	24	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
	25	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
	26	70	70	71	71	72	72	73	74	74	75	75	76	76	77	78	78	79
	27	71	71	72	72	73	74	74	75	76	76	77	77	78	79	79	80	81
	28	72	72	73	74	74	75	76	76	77	78	78	79	80	80	81	82	82
	29	73	73	74	75	75	76	77	78	78	79	80	81	81	82	83	83	84
	30	74	74	75	76	77	77	78	79	80	81	81	82	83	84	84	85	86
	31	75	75	76	77	78	79	80	80	81	82	83	84	84	85	86	87	88
	32	76	76	77	78	79	80	81	82	83	83	84	85	86	87	88	89	90
	33	77	77	78	79	80	81	82	83	84	85	86	87	88	89	90	90	91
	34	78	79	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
	35	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
	36	80	81	82	83	84	85	86	87	88	89	90	91	92	94	95	96	97
	37	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	97	99
	38	82	83	84	85	86	87	89	90	91	92	93	95	96	97	98	99	100

Figure 2. *Temperature and humidity index in livestock production*
Source: *D.M. Amaral-Phillips (2021)*

According to the data obtained, the decrease in the consumption of dry matter in the diet was 6-30%, the decrease in milk productivity was 15-20%, and the decrease in reproductive functions was 40-50%. Animal mortality increased by 1.72%.

Especially under the influence of heat (Schüller *et al.*, 2013):

• food intake decreases, as a result of which less mucus is produced and it is insufficient to neutralize scar acid; with an increase in the content of concentrates in the diet to compensate for the decrease in food consumption, sheep consume more feed, eat large portions and irregularly;

• the frequency of breathing increases, respiratory alkalosis occurs, which leads to excess release of CO_2 from the body; the concentration of HCO_3 in the blood and saliva decreases;

• with an increase in the frequency of breathing, salivary secretion decreases – an additional loss of the buffer effect;

• eating behavior changes. In the process of fodder fermentation, heat is produced in the rumen, and in order to maintain a stable body temperature in the heat, the sheep eats less.

In order to maintain vital activity and functioning of the organism in a stable state, homeothermy works. Deviation from the specified level of body temperature in the conditions of a hot and humid environment leads to interference in physiological processes and, as a result, negatively affects the productivity of animals.

Properties of the skin and fur, sweating and breathing capacity, tissue insulation, ratio of surface area per unit of body mass or uniform lung size, endocrine profiles and metabolic heat generation are these factors affecting heat loads (Key *et al.*, 2014) . For example, in cattle, even a small heat loss at a temperature of 22°C and relative humidity of 50% leads to a loss of 1.1 kg/head/day. With strong thermal stress (30°C and 75% relative humidity), this indicator increases to 3.9 kg/h/day. The health of animals also suffers, their reproductive performance decreases (Fig. 3).

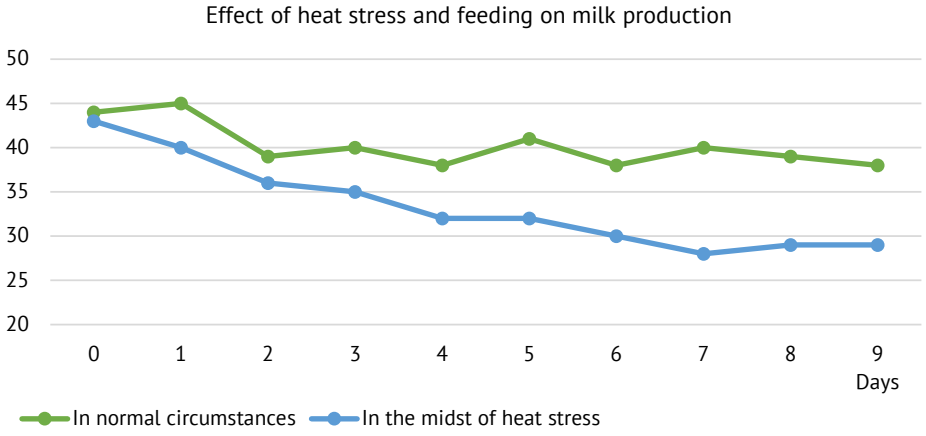

Figure 3. *Influence of warmth and feeding on milk production of cows*
Source: *M. Rhoads et al. (2009)*

Holstein Breed cows in mid-lactation were either subjected to heat stress (THI=~80 for 16 h/day) for 9 days, or remained under normal conditions (THI=~64 for 24 h/day) but received the same amount of dry substances, as animals under heat stress, that is, the same level of feed consumption was maintained. Experimental cows were housed on a farm at the University of Arizona and individually fed an ad libitum mixed diet consisting of alfalfa hay and flaked corn that met or exceeded nutrient requirements (Rhoads *et al.*, 2009). Production losses in domestic animals are largely associated with increased costs of maintaining requirements associated with maintaining a constant body temperature and changing feed consumption (Nezhlukchenko, 2013; 2016). The methods of feeding domestic animals are universal and help the animal to deal more easily with the threat of heat stress.

Recommendations for alleviating the condition of animals from heat stress. A. Yashnikov (2021) defined 6 steps on the way to reducing the negative impact of high temperatures and humidity. The first step is to regulate the number of livestock. Actually, this is one big zootechnical event, when the available resources are rationally redistributed and used. Step number two should be active ventilation of the premises. The presence of ventilators is not a whim, but an urgent necessity. They must be present to ensure air circulation and a normal microclimate. Step number three – increasing the frequency of feed distribution, it is about full-fledged work with feeding.

Ensuring access to water is the logical fourth step, zootechnical standards must be met in relation to the front of the filling and the optimal speed of filling the drinking troughs must be observed, responsible officials must be appointed to control them cleaning The fifth step is high-quality fresh feed. If the technology of fodder preparation is not observed, if inoculants and preservatives are used, then at elevated air temperatures, the fodder will not be able to show the characteristics of thermal stability, it will quickly spoil and lose nutrients.

And the last, sixth step is work with a ratio. Some companies (Lallemand Animal Nutrition, Burgos and Collier) offer solutions related to the use of antioxidants and yeast, but at the moment of heat stress, antioxidants reduce the production of free radicals, which negatively affect the animal's immunity, which, in particular, means on reproductive functions. Heat-stressed yeast in camphor is necessary to maintain the functions of the rumen, help the rumen to digest fiber and reduce the production of heat energy. As a result of their treatment, pH indicators improve, rumination is stimulated (Heat stress affects..., 2013).

Also according to N.D. Olshevska (2018) there are other possibilities of providing animals with comfortable conditions without thermal stress:

1. Water. During the heat stroke, the requirements for the provision of water for sheep are met, among which the following should be noted:

• Fresh, clean, high-quality water with a temperature of +10...+20°C;

• Protection of pumps with shadow canopies;

• Additional pumps.

2. Feeding. During heat stress, it is critically important to improve feeding management. The main measures include:

• Distribution of fresh feed during cooler periods of the day;

• Adherence to the adequate feeding front;

• Smooth covering of the feed table. Protection of feed tables with shade canopies;

• Adaptation of diets during heat stress;

• Absence of secondary fermentation (heating) of feed;

• Thorough and timely cleaning of feed residues from feeders.

3. Shady nightingales in open enclosures. It is critically important to protect animals from direct sunlight in feeding and resting areas. For this, it is necessary to ensure:

• Covered area – 3.5-4.5 m^2;

• The height of the lateral open space is 4.3 m or more.

• Uniform temperature inside the room for maintenance;

• Protection against flies.

4. An effective measure to reduce the negative impact of heat stress is proper ventilation and cooling, the purpose of which is to ensure the appropriate frequency of air replacement in the animal housing and prevent them from overheating.

5. Spontaneous removal of manure, which creates additional heat.

Levucell SC holds the leading positions in the market of yeast probiotics in France, Germany, Great Britain, and the Netherlands. It is a live yeast strain specially selected for its effectiveness on the rumen environment. This yeast is able to stimulate the mechanisms of disposal of excess lactic acid in the rumen, optimizing the pH of the rumen environment, as well as to dispose of rumen, which suppresses the cinnamon microflora of the rumen. In general, feeding Levucell SC, stimulating the development of the cellulolytic microflora of the rumen, makes it possible to obtain more energy from the volumetric part of the diet (The only rumen yeast…, n.d.).

Substances with pronounced antioxidant properties are used for the prevention of radiation damage: vitamins C, E, carotenoids. Effective microelements: zinc, copper and selenium. Selenium, for example, is a part of glutathione peroxidases, which perform the functions of regulating circulatory processes in the body. Selenium also improves the effect of vitamin E, but usually it is not enough in the feed and additional introduction of this element into the feed is required. The problem with selenium also lies in the fact that in ruminants, mineral salts containing selenium are absorbed half as effectively as in poultry and pigs. This is caused by the interaction with the microflora of the rumen. The way out of this situation could be the use of organic forms of selenium. For example, Alkosel R397, it is an inactivated yeast grown in an environment that is poor in zinc, but contains selenium. Such yeast contains selenium-containing amino acids, which, without destroying the microflora of the rumen, are incorporated into the protein composition of the cow's body, releasing selenium as needed. The guaranteed high concentration of organic selenium in combination with the high availability and assimilation of this form ensures the full effectiveness of Alkosel R397 (Selenium-enriched inactivated…, n.d.).

Therefore, in order to prevent the occurrence or alleviate the state of heat stress, it is necessary to pay attention to the diet, its balance and nutrition, parameters of the microclimate of livestock premises, distribution of cattle yards, water regime, organization of walks, etc.

DISCUSSION

When the ambient temperature approaches the sheep's body temperature, the high RH% of the ambient relative humidity reduces evaporation, overloading the sheep and their cooling capacity. This is related to the negative effect of high RH% on the dissipation of body heat, due to a decrease in the effectiveness of radiation, conduction and convection, in addition to a decrease in the effectiveness of evaporative cooling, which is necessary to maintain the heat balance. Such stresses can disrupt the physiology and productivity of animals (Heat stress…, 2020).

Heat loss affects the productivity of small ruminants at all stages of production. The degree of impact of this measure on productivity will differ in different agro-ecological regions and between production systems. The level of productivity achieved by a certain genotype in the environment depends on the appearance and manifestation of many signs, which can be divided into those directly related to production and adaptation (Key *et al.*, 2014).

Traditionally, breeders are guided by knowledge about the regularity of the inheritance of biological and economic traits, and the existing level of productivity, which is determined by hereditary factors and environmental conditions. The rational use of knowledge largely determines the result of the technological selection process (Mamedov, 2021).

Current sheep breeders V. Sukharliov & O. Derevyanko (2003) note that the available sheep breeding technologies are more intensive compared to the last century. But they draw attention to the fact that the appropriate values of animal productivity indicators: a high level of productive signs and the ability to provide high-quality production are determined by genetic factors. According to the requirements of intensive production, sheep must have a strong constitution, resistance to diseases, and be well prepared for breeding in the conditions of various technologies. It is also important to be short-lived and to be able to compensate for feed consumption with good production.

At the physiological level, sheep adapted to one diet demonstrate a high ability to concentrate feces. This is achieved with the help of the kidney, which has the same medulla, which can produce highly concentrated

urine up to 3900 mOcm/l in the native pustule ram and 3244 mOcm/l in the A sheep. compared with values of about 769 mOcm/l in the feces of the Avaci sheep, which got drunk At the same time, the loss of water with feces is minimized, since dehydration slows down the transit of feed in the digestive tract, which leads to greater reabsorption of water and hardness of feces (Hijazi *et al.*, 2014).

Sheep breeds are distinguished by their ability to overcome water shortages; The ibex (*Ovis canadensis nelsoni*) can survive the absence of water for up to 15 days, while Barki sheep in Egypt can survive 3 days without drinking. The rumen plays an equally important role in water conservation in animals adapted to dry conditions, thanks to which it can act as a water reservoir to replenish lost blood volume. Rehydration of adapted water-deprived sheep activates a coordinated cascade of events from the rumen, kidney, and salivary glands under hypothalamic control to conserve water, restore homeostasis and appetite, and prevent water toxicity. Finally, animals adapted to humid conditions can tolerate a slight increase in body temperature during the hottest part of the day with subsequent cooling of the body at night due to conduction and radiation. The ability to tolerate this increase in body temperature means that less water is needed for evaporative cooling (Chedid *et al.*, 2014).

Animals that adapt well to environmental conditions are highly productive. The best adaptation to climatic conditions is noted in local local breeds, such as the traditional breeds of Turkey: Akkaraman, Morkaraman, Dağlıç, İvesi, Kıvırcık and others (Aytekin & Öztürk, 2012). Sheep are characterized by their small size, excellent endurance, and the ability to provide offspring, wool, milk and meat in conditions of limited feeding. A number of scientists call the Romanov breed of sheep the world leader in terms of reproduction and productivity, based on one ewe, technological features such as shortness, polyelectricity, rich fertility, combined productivity and the ability to adapt to various climatic and technological conditions, the ability to transmit accumulated characteristics to offspring (Iovenko, 2017).

The period of reproductive development may depend on dehydration. Animals suffering from water loss often reduce their feed intake, which, according to a study by a group of Australian scientists W.H.E.J. van Wettere *et al.* (2021), causes delay in the mouth of ovarian follicles. In arid and semi-arid regions, where differences in daylight, as well as in the availability of food and water, are clearly visible, the breeding season usually lasts from June to October. Therefore, lambing occurs mostly between February and April, when food and climate are more favorable for newborn survival and milk production. Heat stress impairs the reproductive performance of sheep, and in today's climate is a significant risk to the efficiency of meat and wool production, with impacts increasing as global temperatures rise. Results from field and environmental chamber studies demonstrate that the effects of high temperatures (≥32°C) on ewe fertility (estrus, fertilization, embryo survival and lambing) are most devastating when experienced 5 days before and 5 days after estrus. Temperature-controlled studies also show that ram fecundity, as measured by fertilization rate and embryo survival, is reduced when mating occurs between 14 and 50 days after severe heat (Wettere *et al.*, 2021).

Therefore, in sheep adapted to a hot climate, morphological changes are observed to preserve water in the body (fleece type and color, presence of a fat tail, ability to concentrate feces and have dry excrement, etc.). Also, they have a certain adjusted "schedule" of breeding, which allows for better preservation of newborn lambs along with the availability of feed.

CONCLUSIONS

Global climate changes associated with the variability of weather conditions affect agricultural production in general and livestock production in particular. The priority in the context of world food security is the implementation of urgent measures and the search for long-term strategies to prevent the possible consequences of climate change. Research shows a direct relationship between the temperature-humidity index and indicators of animal body temperature, frequency of respiratory movements and pulse, which are widely used to assess the clinical condition during heat stress. In tropical and equatorial climates and during the summer in temperate regions, overheating is the same threat as cold. In hot conditions, many warm-blooded animals, including sheep and goats, increase heat loss by increasing respiration, evaporating moisture in the lungs, and increasing blood flow through the skin. Reducing or preventing the manifestation of heat stroke in sheep is possible when using physical, physiological, and nutritional methods (regulation of livestock density, access to clean water, preservation of feed from heating, ventilation of premises, etc.). This study is of great value when planning and designing sheep farms or enterprises in the south and east of Ukraine, keeping sheep flocks in an arid climate. In further work, it is planned to investigate the components that can benefit the sheep farming areas and to practically test the above mentioned technologies to reduce the thermal stress of sheep.

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Scientific leader: T.I. Nezhlukchenko, Doctor of Agriculture, Professor.

CONFLICT OF INTEREST

None.

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Вплив теплого посушливого клімату на овець

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Анотація. Породи овець, які походять із посушливих і напівпосушливих регіонів, відомі своєю здатністю адаптуватися до сільського середовища, кліматичних коливань, а також до нестачі ресурсів. Дефіцит води, який часто поєднується з тепловим стресом, є актуальною проблемою вівчарства посушливих регіонів, з якою стикаються ці тварини, спричиняючи фізіологічні порушення та впливаючи на продуктивність тварин. Метою роботи є визначення впливу цієї проблеми на дану галузь тваринництва і пошук кроків на шляху до зниження негативного впливу високих температур і вологості. В ході написання статті було використано теоретичні загальнонаукові методи дослідження і аналіз даних з університетів США, Бразилії, Казахстану, Австралії, Турції та Монголії. Після проведеного аналізу досліджень та їх узагальнення, також надається інформація про особливості районування і клімату України, що впливає на галузь вівчарства. Розглянуто ступені впливу високої вологості повітря і температури на появу стресу у овець. Встановлено, що тепловий стрес є найважливішим кліматичним фактором, який негативно впливає на тваринництво, а іноді навіть загрожує виживанню тварин. Серед кліматичних компонентів, які можуть спричинити стрес на різні якості овець, є температура навколишнього середовища, вологість, рух повітря, фотоперіод, сонячна радіація, швидкість вітру тощо, з яких температура навколишнього середовища є найважливішою змінною. Незважаючи на те, що вплив породи може бути значним, при використанні методу спостереження за поведінкою тварини можна окреслити наступні загальні реакції на посуху та тепловий стрес: зниження споживання корму та втрата ваги, посилення охолодження через випаровування при диханні, утворення невеликої кількості висококонцентрованої сечі, гемоконцентрація, висока осмоляльність крові та імуносупресія. Полегшення теплового стресу тварин за допомогою фізичних, фізіологічних та/або харчових методів, на додаток до дотримання належних практик управління у відповідний час, може допомогти тваринам, які зазнали теплового стресу, реалізувати свій генетичний потенціал у спекотних і посушливих регіонах, що і є практичною цінністю

Ключові слова: тепловий стрес; продуктивність; температура навколишнього середовища; жировий хвіст; природно-сільськогосподарське районування території

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Nutrient regime of the soil depending on the share of sunflower in short-rotational crop

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Abstract. Sunflower requires a sufficient amount of nutrients for growth and development. Therefore, it is important to determine the impact of sunflower cultivation on the soil nutrient regime, taking into account the frequency of its return to the previous place. The aim of the study was to determine the influence of the share of sunflower in short rotation crop rotations on the soil nutrient regime. The research was conducted at the experimental field of the Kharkiv V.V. Dokuchaev National Agrarian University, which is located in the Left-Bank Forest-Steppe of Ukraine. The research and accounting were carried out on typical heavy loamy chernozem in accordance with generally accepted methods. The experimental scheme included five-field crop rotations with sunflower saturation of 0, 20, 40 and 60%. The research results show that an increase in the share of sunflower in short rotation crop rotations does not lead to a deterioration in the nutrient regime of the topsoil. There was no significant difference between the variants in the content of nutrients. The most supplied with nutrients was the topsoil in the control variant (crop rotation without sunflower). With an increase in the share of sunflower in crop rotations, the amount of nutrients in the tilth layer of soil decreased slightly. Regardless of the studied crop rotation options, the availability of easily hydrolysable nitrogen was low, mobile phosphorus was average, and exchangeable potassium was high. Increasing the share of sunflower in short rotation crop rotations led to a decrease in the yield of the crop itself. The yield of sunflower seeds was at the same level in the variants with 20 and 40%. There is a close relationship between sunflower yield and its saturation, which significantly depends on the soil nutrient regime. The yield level is most affected by the content of phosphorus and potassium in the topsoil. The correlation is 0.91 and 0.98, respectively. The practical value of this study is due to the possibility of using the obtained results to justify the feasibility of increasing the share of sunflower in the structure of crop rotations

Keywords: saturation; structure of crop rotation; fertility; correlation dependence; nutrients; typical chernozem

INTRODUCTION

It is known that plants primarily require a sufficient amount of nutrients. Optimising the supply of nutrients during the growing season of crops results in more efficient use of moisture, regardless of the conditions prevailing during the growing years (Pinkovsky *et al.*, 2019). This was determined during research with various crops, including sunflower (Domaratskiy *et al.*, 2019; Gamayunova *et al.*, 2019). Data obtained by scientific institutions indicate that sunflower should occupy no more than 20% of the crop rotation structure (Tkalich *et al.*, 2018). Under current farming conditions, increasing the share of sunflower in short rotation crop rotations is quite common. Increased profits from sunflower cultivation encourage most farms to abandon science-based technologies, which is manifested in a high degree of saturation of crop rotation

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with sunflower. Under current agricultural conditions, intensive saturation of short rotation crop rotations with sunflower is often practiced. Usually, it can be returned to the previous place of cultivation after 2-3 years (Bojko & Borodan, 2000; Shevchenko *et al.*, 2001). However, in this case, the yield may decrease to 0.9 t/ha in the third year of cultivation (Hanhur *et al.*, 2015).

Some studies show that an increase in the share of sunflower in the crop rotation above the recommended level leads to negative consequences for the water and physical properties of the soil, the phytosanitary condition of crops, and the emergence of infections. In addition, if fertilisers are not applied in the required amount, there is a significant decrease in the content of nutrients (including nitrogen, phosphorus and potassium) in the soil. In this case, the humus content in the soil decreases, which leads to other degradation processes (Poliakova & Topchiy, 2013; Tsyliuryk, 2018).

The nutrients in the soil have a significant impact on the growth and development of sunflower, as well as on its productivity. Depending on the phenological stage, sunflower requires different nutrients. At the beginning of sunflower growth and development, nitrogen is needed in the first place. From this point on, it accumulates in the stems and leaves, and later in the baskets. The absorption of nitrogen ends at the time of flowering, after which this element is transported through the plants in the form of amino acids. Providing plants with sufficient nitrogen contributes to the formation of more flowers, slower aging of leaves after flowering and greater accumulation of protein compounds in seeds. Phosphorus provides the energy basis for biochemical processes in sunflower plants. It is a component of nucleic acids, nucleotides, enzymes and products of the photosynthetic and respiratory cycles (Getie *et al.*, 2021). Phosphorus is absorbed by sunflower from germination to flowering. It contributes to the formation of a powerful root system, the laying of reproductive organs with a larger number of embryonic flowers in the basket, accelerates plant development, and increases drought resistance. Despite the high potassium requirement of sunflower, it has an average effect on yields (Hospodarenko, 2018). Many scientists believe that an increase in the share of sunflower in crop rotation negatively affects the balance of nutrients in the soil.

Scientifically based crop rotation in time and space ensures high yields and productivity of crop rotations. For example, researchers note that crop rotations with 20% of fallow land and 10% of sunflower and corn for silage have the highest productivity. At the same time, out of 60% of grain crops, winter crops accounted for 40% (wheat and barley), and peas and corn for 10% each (Sayko & Boyko, 2002; Giannoulis *et al.*, 2009).

The aim of the study was to determine the effect of short rotation crop rotations with different proportions of sunflower on soil nutrient supply.

MATERIALS AND METHODS

The field research was conducted at the stationary of the O.M. Mozheiko Department of Agriculture of the Dokuchaevske Experimental Field Educational and Research Centre. The soil cover of the experimental field is represented by typical heavy loamy chernozem on loess loam. In terms of agrophysical and agrochemical properties, it is one of the most favourable soils for growing field crops. It is characterised by a high level of fertility. The topsoil (0-30 cm) of a typical black soil contains 4.9-5.1% humus (according to Tyurin), 81 mg/kg of easily hydrolysable nitrogen (according to Kornfield), and 100 and 200 mg/kg of mobile phosphorus and exchangeable potassium (according to Chirikov). The content of exchangeable cations: calcium – 37.8%, magnesium – 6.6%, sodium – 0.49%, potassium – 0.5%. Soil reaction – pH: water – 7.0, salt – 5.2-5.6. Groundwater is located at a depth of about 18 m (Tykhonenko & Dehtiarov, 2016).

The sunflower hybrid is Cruiser LG59580. The experiment was replicated three times, with a sequential arrangement of variants. The size of the sowing plot was 750 m^2, the accounting plot was 100 m^2. The research conducted with sunflower was carried out in accordance with international ethical standards, in particular The Convention on Biological Diversity (2022). Variants of short-rotation (5-field) crop rotations with different proportions of sunflower in the structure of sown areas were studied (Table 1). The control variant was a five-field crop rotation without sunflower.

Table 1. *Crop rotation structure, %*

Peas	Winter wheat	Corn	Winter rye	Pure fallowing	Sunflower
20	20	20	20	–	20
20	20	-	20	–	40
-	20	-	20	–	60
	20	40	20	20	0

Source: *developed by the author*

The content of nutrients in the soil was determined in accordance with generally accepted methods: the content of easily hydrolysable nitrogen – by the Kornfield method (DSTU 7863:2015, 2016), the content of

mobile phosphorus and potassium compounds – by the modified Chirikov method (DSTU 4115:2002, 2003). Statistical processing of the data was carried out using the CORREL function, which is part of the data analysis package in MS Office Excel 2017.

Moisture conditions and temperature have a particularly important impact on the efficiency of nutrient fixation in the soil (Liu *et al.*, 2011; Rymuza *et al.*, 2020). The research was conducted in an area with a temperate continental climate. It is characterised by elevated air temperatures and low precipitation compared to long-term averages.

Data from the weather station of Kharkiv National Agrarian University show that during the growing season of sunflower (May-September), the average long-term rainfall was 278 mm and the air temperature was +17.7°C. The peculiarity of the conditions in 2020-2021, during the period of determination of NPK (nitrogen, phosphorus, potassium) in the soil, was insufficient moisture. During the growing season of sunflower in 2020, precipitation was 114 mm less than normal, and the average air temperature was 19.8°C, which is 2.1°C above the climatic norm. The precipitation during the growing season of sunflower in 2021 was of a stormy nature in June – 81.9 mm, which was 22.9 mm above the average long-term norm. In July and August, they were less than the long-term average by 51.5 and 44.2 mm, respectively. In 2021, precipitation totalled 197.7 mm, which is 81.3 mm less than the long-term average, and the increase in average daily air temperature was 2.5°C above the long-term average. Having analysed the weather conditions, we can conclude that heat and moisture supply significantly influenced the growth and development of sunflower, and ultimately its yield and seed quality.

RESULTS

The research results allow us to determine the level of soil nutrient supply under conditions of different saturation of short-rotation crop rotations with sunflower.

Nitrogen. In the phase of full ripeness of sunflower, the studied samples were characterised by low supply of easily hydrolysable nitrogen in all variants (Fig. 1). Depending on the proportion of sunflower in the crop rotation, this indicator varied within 151-123 mg/kg of soil. Its highest content (151 mg/kg of soil) was found in the surface (0-10 cm) soil layer at 40% saturation of the crop rotation with sunflower, and the lowest (123 mg/kg of soil) in the layer 20-30 cm in the variant with a share of sunflower of 60%. The nitrogen content in the soil in the plots with other variants varied only slightly. The content of this element was relatively higher in the 0-10 cm soil layer – 145-151 mg/kg of soil.

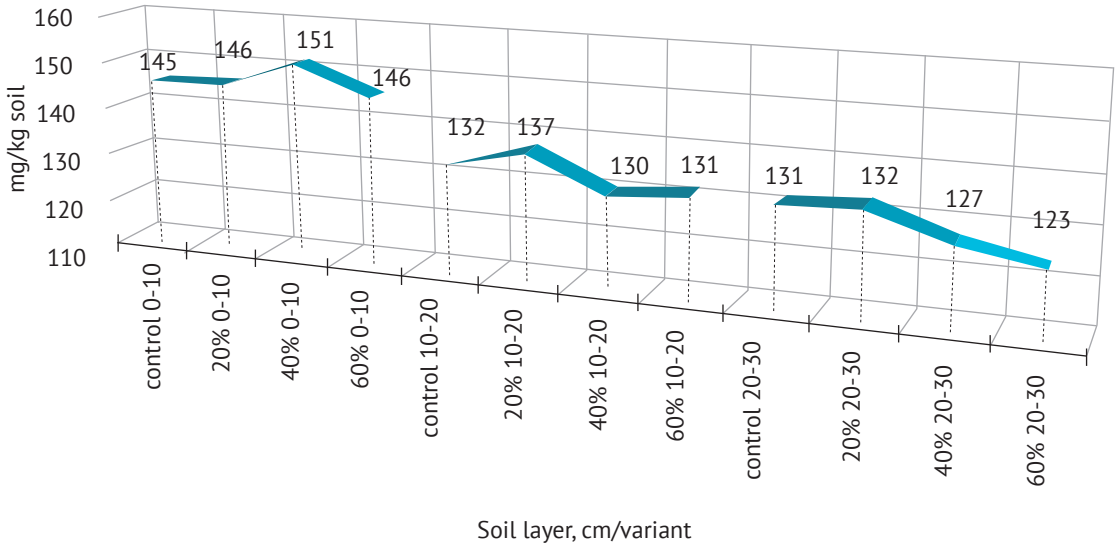

Figure 1. *The content of easily hydrolysable nitrogen in the soil depending on the saturation of the crop rotation with sunflower, mg/kg of soil*

Source: *developed by the author*

Phosphorus. The processes of biological accumulation of phosphorus in the bedrock affect the content of its mobile compounds throughout the soil profile. Thus, the studied samples were characterised by an average supply of mobile phosphorus forms in all variants (Table 2). The content of P_2O_5 in the arable layer of typical black soil in sunflower crops was almost equal in the experimental variants. It should be noted that the content of this macronutrient was significantly higher in the upper (0-10 cm) soil layer than in the lower part (20-30 cm) of the tilth layer. Compared to the control, a significant decrease in P_2O_5 was recorded in the variant with a crop rotation saturation of 60% with sunflower, by 1.4 times.

Table 2. *The content of mobile phosphorus in the soil depending on the saturation of crop rotation with sunflower*

Share of sunflower in crop rotation	P_2O_5 content, mg/kg by soil layer		
	0-10cm	10-20 cm	20-30 cm
20%	100	66	65
40%	99	64	64
60%	66	63	54
0%	97	73	74

Source: *developed by the author*

Potassium. Sunflower is known to use potassium intensively. Samples of the tilth layer of typical chernozem were characterised by an increased availability of mobile potassium compounds in all variants, and their content naturally decreased with depth from 81 to 115 mg/kg of soil. In the surface soil layer, the highest content of potassium was observed in the variant without sunflower – 115 mg/kg of soil (Table 3). In the crop rotation with a share of sunflower of 40%, the content of exchangeable potassium compounds in the 0-10 cm soil layer was almost at the level of the control – 113 mg/kg of soil. There was no significant difference between the K_2O content of other variants in this layer: 107 mg/kg soil (20% saturation) and 103 mg/kg soil (60% saturation).

Table 3. *Exchangeable potassium content in soil depending on the saturation of crop rotation with sunflower*

Share of sunflower in crop rotation	K_2O content, mg/kg by soil layer		
	0-10 cm	10-20 cm	20-30 cm
20%	107	85	82
40%	113	86	84
60%	103	83	81
0%	115	94	90

Source: *developed by the author*

With a depth of 20 cm, a decrease in the content of exchangeable potassium was observed in all variants. In the soil layer of 10-20 cm, the highest content was found in the control variant at 94 mg/kg of soil. Similar results were obtained in other crop rotations and were in the range of 83-86 mg/kg of soil. In short-rotation crop rotations, a decrease in the content of exchangeable potassium compounds was observed in the soil layer of 20-30 cm, depending on their saturation with sunflower. In the soil of the control variant, the content of this element was 90 mg/kg of soil, which is 9 mg/kg more than in the variant with 60% sunflower saturation. An increase in the share of sunflower in the crop rotation to 40% increased the content of exchangeable potassium in the soil by 2 mg/kg of soil and by 3 mg/kg of soil at 60% saturation.

Sunflower yield. In the course of research in 2020, a relationship was established between the level of sunflower yield and its saturation in crop rotations (Table 4). It is worth noting the high yield of sunflower at 40% of its saturation in crop rotation – 3.77 t/ha. Saturation of the five-field crop rotation with 60% of sunflower reduced the yield to 3.24 t/ha.

Table 4. *Sunflower yield in different short rotation crop rotations*

Share of sunflower in crop rotation	Yield, t/ha	
	2020 year	2021 year
20%	3.73	3.13
40%	3.77	3.36
60%	3.24	3.17

Source: *developed by the author*

In 2021, the high yield of sunflower (3.36 t/ha) was ensured by a five-field crop rotation with a share of 40%. When the crop rotation was saturated with sunflower up to 20% and 60%, there was a slight decrease in sunflower yield by 0.23 and 0.19 t/ha. On average, in 2020-2021, the highest sunflower yield (3.57 t/ha) was recorded in the

five-field crop rotation, where its share was 40%. When the crop rotation was saturated with 20% of sunflower, there was a slight decrease in its yield – by 0.14 t/ha. Saturation of the crop rotation with sunflower up to 60% led to a significant decrease in its yield by 0.36 t/ha compared to the best variant of the experiment (Fig. 2).

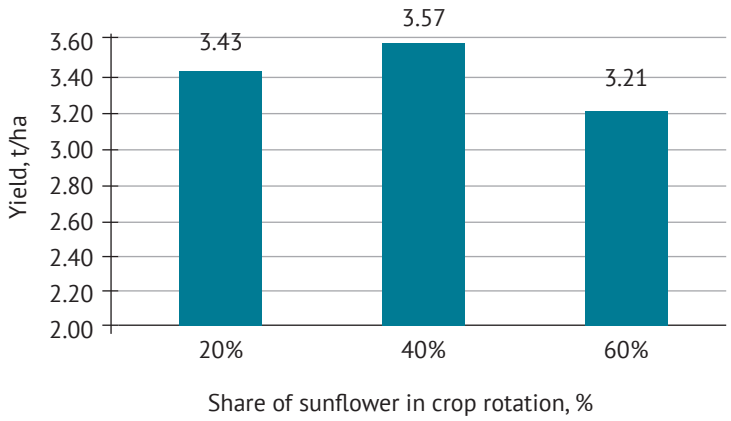

Figure 2. *Sunflower yield depending on its share in crop rotation, t/ha (average for 2020-2021)*
Source*: developed by the author*

Dependence of sunflower yield on NPK content. The statistical analysis showed a close correlation between sunflower yield and the content of macronutrients in the soil in crop rotation areas with different soil saturation. The equation for the correlation coefficient between sunflower yield and soil nutrient content is as follows:

$$Correl\ (X,Y) = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}},$$

where x – yield, t/ha; y – nutrient content in the soil, mg/kg soil.

The data obtained indicate that sunflower yields are most closely related to soil K_2O content. The correlation coefficient between these indicators was the highest and amounted to 0.98. The content of mobile phosphorus in the soil was equally important for sunflower yield, with a correlation coefficient of 0.91. There was a direct correlation between sunflower yield and soil nitrogen content – 0.66.

DISCUSSION

It is known that nitrogen assimilation through the symbiosis of microorganisms with plants provides the soil with 90-170 million mg of nitrogen annually (Ishizuka, 1992; Kozłowski *et al.*, 2011; Tsyliuryk, 2018). This is 70-80% of the total amount of nitrogen accumulated in the soil in the process of nitrogen fixation by all microorganisms (symbiotic and free-living) (Peoples & Craswell, 1992; Cheng, 2008; Martyniuk, 2012). The efficiency of atmospheric nitrogen reduction in symbiotic systems usually reaches up to 200 kg N ha^{-1} (but sometimes even 500 kg N ha^{-1}) per year (Duzdemir *et al.*, 2009; Hauggaard-Nielsen *et al.*, 2010).

Previous studies have shown a significant reduction in nitrogen content under no-till sunflower cultivation in the 0-20 and 20-40 cm soil layers: 8.9 and 6.6 mg/100 g of soil, respectively. Zonal crop rotation provided a high phosphorus content in the soil: 10.4 mg/100 g in the 0-20 cm layer and 7.7 mg/100 g in the 20-40 cm layer, and the lowest content in virgin soil (5.8 mg/100 g in the 0-20 cm layer and 4.8 mg/100 g in the 20-40 cm layer). The studied variants of crop rotation did not have a significant effect on the content of exchangeable potassium in the soil, and its amount was quite high in all soil samples (8.0 mg/100 g to 13.3 mg per 100 g of soil). It should be noted that permanent sunflower cultivation provided the topsoil with an increased potassium content (Poliakova & Topchiy, 2013).

Soil nutrient regime largely depends on the saturation of crop rotations with sunflower. Researchers say that an increase in the share of this crop in crop rotation causes an increased level of nutrient removal from the soil. This can have a negative impact on the growth and development of subsequent crops. According to the results of research by A. Kokhan *et al.* (2018) found that a crop rotation with 14% sunflower provided a higher content of nutrients in the 0-10 cm soil layer than a crop rotation with 50% of this crop. The total removal of NPK by sunflower was 75.3 kg/ha. It was found that for growth and development during the growing season, sunflower requires the most exchangeable potassium (178.8 kg/ha). At the same time, only 20% of the potassium is removed with the harvest, while the rest remains in the soil with non-commodity products. Therefore, to compensate for the macronutrients removed from the soil by sunflower, it is necessary to leave crop residues on the field. This will help prevent degradation processes and help maintain soil fertility.

Some researchers point out that a significant portion of the total nutrient content absorbed and accumulated

by sunflower plants remains in the field after harvesting in the form of crop residues. After mineralisation of crop residues, these nutrients are easily available to the next crop, which is very important in a crop rotation system (Castro *et al.*, 2014). Depending on the amount of nutrient removal with the crop, the crops included in the studied crop rotations are distributed in the following order sugar beet – 163.2 kg/ha, maize – 97.5-156.5, soybeans – 111.3-115.1, winter wheat – 108.9-131.6, spring barley – 102.1-112.9, vetch-oat mixture – 112.9, sunflower – 85.3-109.7, peas – 72.4-79.6 kg/ha; in terms of phosphorus removal – corn for grain – 37.6-56.2 kg/ha, winter wheat – 41.0-48.9, sunflower – 36.6-45.0, sugar beet – 41.9, vetch-oat mixture – 38.6, spring barley – 32.5-38.0, soybeans – 33.3-33.9, peas for grain – 19.2-31.1 kg/ha; in terms of potassium removal – sugar beet – 187, vetch-oat mixture – 115.3, sunflower – 72.1-103.2, corn for grain – 65.8-103.0 kg/ha

Yu.I. Tkalich (2017) emphasises that the largest biological nitrogen removal is caused by corn (106.06 kg/ha), followed by rapeseed (92.29 kg/ha), winter wheat (82.54 kg/ha), sunflower (73.12 kg/ha), and spring barley (52.4 kg/ha). Corn consumes the most mobile phosphorus compounds (25.78 kg/ha), followed by rapeseed (24.57 kg/ha), slightly less winter wheat (21.16 kg/ha), and even less sunflower (17.68 kg/ha) and spring barley (16.28 kg/ha). Corn also absorbs the most exchangeable potassium (18.35 kg/ha), followed by rapeseed, sunflower and winter wheat (17.89, 14.28 and 14.01 kg/ha), and spring barley (10.78 kg/ha).

In the experiments of S. Kudria (2020), no clear dependence of nutrient content on crop rotation was found. According to O. Tsyliuryk (2018), sunflower removes 120-140 kg/ha of nitrogen, 50-65 kg/ha of phosphorus and more than 300 kg/ha of potassium from the soil to form 2.0-2.5 t/ha of yield. Some authors point out that saturation of crop rotations with sunflower over 50% negatively affects the level of its yield (2.21 t/ha), while a decrease to 33% contributes to an increase in crop productivity by 0.29 t/ha. At the same time, the level of sunflower yield in this variant is 0.12, 0.21 and 0.24 t/ha lower than in crop rotations saturated with the crop, respectively, by 25, 20 and 14.3% (Bilenko & Baranenko, 2018).

Similar results were obtained in the fields of the Institute of Steppe Agriculture of the National Academy of Agrarian Sciences of Ukraine (Pohribnyi & Mashchenko, 2021). It has been established that grain and fallow crop rotations with sunflower saturation of 20% and the use of an organic-mineral fertilisation system provide high stress resistance of plants to abiotic factors. This, in turn, ensures a high yield of 2.63 t/ha.

According to V. Hanhur (2016), high culture of farming, adherence to scientifically sound crop rotations, and the use of highly productive hybrids allow saturating field crop rotations with sunflower at the level of 14-15% of the total sown area. Under such conditions, there is no significant decrease in the productivity of both the sunflower and the crop rotation as a whole. At the same time, it allows for the possibility of a one-time increase in the share of sunflower in the structure of crop rotation areas up to 20%.

Some scientists state a decrease in sunflower seed yields (2.19 t/ha) in case of increasing the share of sunflower in crop rotation to 50%. Crop rotations with 33.3 and 25% saturation provided sunflower yields of 2.49-2.61 t/ha. If crop rotations are saturated with sunflower by only 20 and 14.3%, a fairly high yield can be obtained: 2.70 and 2.75 t/ha. This is by 0.26-0.56 t/ha higher than when the crop rotation is saturated with sunflower by 50.0% and 33.3%. These data are confirmed by parallel studies on growing sunflower in crop rotations. Kokhan *et al.* (2015) noted a gradual decrease in yields when the crop rotation was saturated with sunflower to 20, 25, 33.3, and 50%. Especially in two- and three-crop rotations: by 0.55 and 0.27 t/ha. According to long-term data from the Mykolaiv State Agricultural Experimental Station, when sunflower was returned to its previous place in the crop rotation after 10, 6 and 4 years, its yield was 2.01, 1.33 and 1.11 t/ha, respectively (Popova *et al.*, 2004).

The research conducted during 2020-2021 shows the expediency of studying the issue of the share of sunflower in short rotation crop rotations. Analyses of the NPK content in the topsoil show that, in general, an increase in the saturation of crop rotations with sunflower to 60% does not reduce the availability of soil nutrients. In turn, the yield data confirm the results of other authors regarding the inexpediency of increasing its share in crop rotation. After all, the yield slightly decreased in the variant with 60% saturation of crop rotation with sunflower to 3.21 t/ha compared to 20% saturation, where the yield is 3.43 t/ha, and at 40% saturation – 3.57 t/ha.

CONCLUSIONS

The increase in the share of sunflower in short rotation crop rotations did not lead to a deterioration in the nutrient regime of the tilth layer of soil. There was no significant variation in the content of nutrients between the variants. The most nutrient-supplied topsoil was in the control variant (crop rotation without sunflower). With increasing saturation of crop rotations with sunflower, the amount of available forms of nutrients in the tilth layer of soil slightly decreased, but within the limits of availability were at the same level according to the experimental variants: easily hydrolysable nitrogen – low; mobile phosphorus – medium; exchangeable potassium – increased.

It was proved that an increase in the share of sunflower in short rotation crop rotations leads to a

decrease in the yield of the crop itself by 0.22-0.36 t/ha. The yield of sunflower seeds was at the same level at 20 and 40% saturation (3.43 and 3.57 t/ha). The relationship between sunflower yield and its saturation in the crop rotation is noticeable, but it depends significantly on the soil nutrient regime. The yield level is most influenced by the content of phosphorus and potassium in the topsoil, with correlations of 0.91 and 0.98 respectively. Further research will be aimed at determining the NPK content of sunflower residues to calculate the balance of these elements in the soil, taking into account the frequency of sunflower return to its original place.

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CONFLICT OF INTEREST

None.

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Поживний режим ґрунту залежно від частки соняшнику у короткоротаційних сівозмінах

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Анотація. Для росту і розвитку соняшнику необхідна достатня кількість поживних речовин. Тому встановлення впливу вирощування соняшнику на поживний режим ґрунту, з урахуванням частоти його повернення на попереднє місце, є актуальним. Метою роботи було визначити вплив частки соняшнику у короткоротаційних сівозмінах на поживний режим ґрунту. Дослідження проводилися на дослідному полі Харківського національного аграрного університету ім. В.В. Докучаєва, яке розташоване в Лівобережному Лісостепу України. Дослідження та обліки були проведені на чорноземі типовому важкосуглинковому згідно із загальноприйнятими методиками. Схема досліду передбачала п'ятипільні сівозміни із насиченням соняшнику 0, 20, 40 і 60 %. Результати досліджень свідчать, що збільшення частки соняшнику в короткоротаційних сівозмінах не призводить до погіршення поживного режиму орного шару ґрунту. Не виявлено суттєвої різниця між варіантами у вмісті елементів живлення. Найбільш забезпеченим поживними елементами був орний шар ґрунту у контрольному варіанті (сівозміна без соняшнику). З підвищенням частки соняшнику у сівозмінах, кількість елементів живлення в орному шарі ґрунту дещо знижувалася. Незалежно від досліджуваних варіантів сівозмін, забезпеченість легкогідролізним азотом була низькою, рухомим фосфором – середньою, обмінним калієм – підвищеною. Збільшення частки соняшнику в короткоротаційних сівозмінах призвело до зниження врожайності самої культури. Урожайність насіння соняшнику знаходилася на одному рівні у варіантах із частками 20 та 40 %. Відмічено тісний зв'язок між урожайністю соняшнику та його насиченням, що значно залежить від поживного режиму ґрунту. Найбільше на рівень врожаю впливає вміст в орному шарі ґрунту фосфору та калію. При цьому кореляційний зв'язок становить 0,91 та 0,98 відповідно. Практична цінність цього дослідження обумовлена можливістю використовувати отримані результати під час обґрунтування доцільності збільшення частки соняшнику у структурі сівозмін

Ключові слова: насиченість; структура сівозміни; родючість; кореляційна залежність; поживні елементи; чорнозем типовий

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