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SUPPORT FOR ENVIRONMENTAL AND ECONOMIC EFFICIENCY OF AGRICULTURAL LAND USE IN UKRAINE IN THE CONTEXT OF CLIMATE CHANGE

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Abstract. *The research focuses on the issue of maintaining environmental and economic efficiency in the use of agricultural land in Ukraine under climate change conditions. The changing climate is adversely affecting the agricultural sector, leading to reduced crop yields, soil degradation, and heightened environmental challenges. In response to these issues, the study develops strategies and measures aimed at ensuring sustainable agricultural development through optimized land resource use. The paper analyzes the current state of agricultural lands, evaluates the impact of climate change on the agricultural sector, and identifies key indicators of environmental and economic efficiency. The proposed methods and approaches are designed to preserve soil fertility, reduce the environmental impact of agricultural activities, enhance economic profitability, and increase the sustainability of the agricultural sector. The results of the study can be utilized to improve national policy in land resource management and the adaptation of the agricultural sector to new climatic realities. The implementation of the research findings is expected to positively impact ecosystem preservation, increase the economic efficiency of the agricultural sector, and improve the well-being* *of rural populations in Ukraine. Consequently, this research makes a significant contribution to the development of scientific knowledge and practices regarding the efficient use of land resources in the context of global climate change.*

Keywords: *land resources, efficiency of agricultural land use, food security, climate change, environmentally safe land use, land protection, erosion control hydraulic structures.*

Problem statement. Climate change is one of the biggest threats to the stability of Ukraine's agricultural sector, which is a key component of the country's economy. The impacts of climate change on agriculture are evident in the increase of extreme weather events, shifts in precipitation patterns, changes in the length of the growing season, as well as in soil characteristics and the intensification of erosion processes. In these conditions, it is particularly important to ensure the environmental and economic efficiency of agricultural land use by preserving and improving its quality, optimising agricultural production in terms of environmental sustainability, and adapting the agricultural sector to climate change.

Ukraine is among the world's leading food suppliers, with agricultural land use covering over 70% of its territory. However, climate change poses a significant threat to the productivity of agricultural lands, leading to decreased crop yields and reduced economic efficiency in agricultural production. The main manifestations of climate change in Ukraine include rising average annual temperatures, changing seasonal precipitation patterns, increasing frequency and intensity of droughts, and the spread of erosion processes.

Climate change also increases the vulnerability of agricultural systems to biotic and abiotic stresses. Rising temperatures can lead to an increased risk of pests and plant diseases, which in turn reduces the quality and quantity of crops. Changes in precipitation patterns complicate water resource management and reduce water availability for irrigation, which is particularly critical for the steppe regions of Ukraine.

The current problems of environmental and economic instability compel the scientific community and practitioners to seek new approaches to the management of natural resources, particularly agricultural lands. The economic efficiency of agriculture remains a vital aspect for farmers and agricultural enterprises. Rising resource costs, including fuel, fertilizers, and crop protection products, require farmers to find new ways to reduce costs and increase profitability. In a global competitive and market instability environment, achieving high economic efficiency is a key factor for the survival and development of the agricultural sector. Therefore, the issue of ensuring the environmental and economic efficiency of agricultural land use is of paramount importance today.

Ukraine's land resources hold special value, as the unique chernozems are rightly considered one of the nation's wealth sources. However, the irrational use of agricultural lands, where short-term goals prevail over long-term ones, leads to soil fertility decline and an increase in degraded, low-productive, and polluted land areas. Therefore, the issue of ensuring environmental and economic efficiency in the use of agricultural lands is of exceptional importance and relevance today.

Analysis of recent research and publications. The scientific works of many domestic scientists are dedicated to studying the problems of effective land use in agriculture by land users, such as agricultural enterprises, farms, and households. Among them are the works of Budzyak V.M., Harazh O.P., Zinchenko O.I., Kulinich P.F., Kuryltsiv R.M., Martyn A.G., Nyvievsky O.V., Nosik V.V., Shulha M.V., and others.

Studies by scientists such as Balyuk S.A., Nosko B.S., Kucher A.V. and others have shown that the soil fertility of arable land in Ukraine is now constantly declining under the influence of both natural and anthropogenic degradation processes. Therefore, finding ways to improve the efficiency of land use becomes extremely urgent in the context of the land market's introduction, and with climate change, its significance will only grow, as this is a key factor in ensuring the country's food security.

The purpose of the study is to analyse the state and dynamics of the efficiency of land use in Ukraine in agricultural enterprises, as well as to substantiate ways to improve the environmental and economic efficiency of agricultural land use in the context of climate change.

Materials and methods of the study. The following research methods were used in the study: a monographic method for reviewing scientific sources on the essence of environmental and economic efficiency of agricultural land use; an abstract-logical method for substantiating the purpose, objectives, and conclusions of the study; a graphical method for visualizing the agricultural efficiency of different regions of Ukraine. The method of systematic analysis was used to study the construction (reconstruction) of anti-erosion hydraulic structures, as well as the use of funds received in the order of compensation for losses in agricultural and forestry production in Ukraine.

Research results and discussion. The basis for sustainable and efficient land use in the agricultural sector is the availability and rational distribution of land between the state, farms, agricultural enterprises and private landowners, which allows balancing the interests of all market participants. Analyzing the structure of land resources by their economic use, it should be noted that a significant level of life space development has formed in Ukraine. Thus, according to the StateGeoCadastre, as of 01.01.2016, the largest share in the structure of the agricultural sector is occupied by agriculture - 69.8% (42131.0 thousand ha), followed by forestry - 14.7% (8868.4 thousand ha), environmental protection - 4.8% (2909.8 thousand ha), and other unused land - 5.4% (3229.3 thousand ha) [1].

It is worth noting that under the planned economy of the Soviet Union, the efficiency of agriculture was primarily determined by its ability to produce products necessary for society, i.e., to provide the population with food and industry with agricultural raw materials. Loss-making activities of economic entities did not foresee their bankruptcy. The state addressed this issue, particularly for collective and state farms, through setting fixed procurement prices, setting low prices for industrial goods for agriculture, periodic debt write-offs, and budget financing.

The transition to a market economy requires a revision and development of certain methodological approaches to assessing the economic efficiency of agricultural production, substantiating mechanisms of state support for the agricultural sector, and ensuring income parity between agricultural enterprises and private farms.

It should be noted that in 1990 agricultural enterprises (collective and state farms) cultivated 30421.8 thousand hectares of harvested area of the main agricultural crops, while household farms used 1984.2 thousand hectares, which accounted for 6.5% of the total harvested area [2]. However, since the beginning of the land reform in Ukraine in 1991, a transformational shift occurred, where more than two-thirds of agricultural lands were transferred to private ownership by citizens and legal entities. This significant redistribution of land ownership introduced a new dynamic in the use and management of agricultural lands, offering owners the flexibility to either cultivate these lands for personal use or lease them, mainly under lease agreements. The efficiency of agricultural operations on these lands is determined by several critical factors, including the quality and geographic location of the plots, climatic and environmental conditions, the entities that oversee them, and the level of technological advancement used in their cultivation.

The environmental and economic efficiency of agricultural land use can be measured using various quantitative indicators that reflect both the economic and environmental aspects of their use. Among the economic indicators, one can highlight the gross output per unit area, which shows the total value of the products obtained from one hectare of agricultural land, allowing for the assessment of land productivity and resource use efficiency. The profitability of agricultural production, defined as the ratio of profit to costs, is another important indicator demonstrating the economic efficiency of land use. Direct costs per unit of production, which include costs for fertilizers, pesticides, seeds, water, energy, and labor, also serve as an indicator of economic efficiency, as lower costs per unit of production indicate more rational resource use. Gross income per unit of land area is another indicator reflecting the total income obtained from one hectare of land, helping to assess the economic potential of land use.

Environmental indicators may include the soil erosion index, which shows the volume of soil lost due to erosion processes per unit area. The lower this index, the better the soil cover is preserved, indicating high environmental efficiency of land use. The organic matter content in the soil is an important indicator of soil fertility. A high organic matter content indicates healthy soil and its ability to sustain productivity in the long term. Greenhouse gas emissions from agricultural land are another important environmental indicator, as they reflect the amount of greenhouse gases produced during agricultural production. The water consumption coefficient, reflecting the amount of water needed to produce one ton of agricultural products, is also an important indicator, as lower water consumption indicates more efficient use of water resources. The biodiversity index, which determines the number of plant and animal species per unit area, is an indicator of the health of the ecosystem, which can support the stability of agro-ecosystems.

Integral indicators, such as the agro-ecosystem sustainability index, which consider yield stability, biodiversity level, soil fertility preservation, and the agro-ecosystem's ability to withstand external stresses, particularly climate change, are of significant interest. Environmental and economic efficiency indices integrate economic and environmental indicators into a general index, reflecting the balance between land use productivity and its environmental sustainability. However, such assessments largely depend on the weighting of the impact of individual indicators on the overall index [3, 4].

However, integral indicators that combine several individual metrics into one general assessment have both advantages and disadvantages. Among the advantages is their ability to cover various aspects, including economic, environmental, and social components, allowing for a comprehensive view of the efficiency or state of a certain system. This is particularly useful for strategic decision-making when it is necessary to assess the overall picture rather than delve into details. Integral indicators simplify analysis, as they reduce diverse data to a single numerical value, making them easier to use in communication with non-expert audiences, such as policymakers or managers. Thus, they can be easily applied to compare different objects or regions according to the same criteria. Also, these indicators allow for generalization, aggregating numerous data into one metric, making it easier to monitor, manage, and report, especially in the context of large systems. Generalization simplifies the decision-making process, as integral indicators provide a convenient tool for evaluating different options and choosing the most optimal one.

However, there are also significant drawbacks. For example, combining several indicators into one integral can lead to the loss of important information. This means that changes in one component may be hidden due to compensating changes in another, making the indicator less sensitive to specific changes. The choice of weight coefficients, determining the importance of each individual indicator in the overall metric, may be subjective and depend on biases or the specific goals of the researcher. This introduces an element of subjectivity into the assessment. In addition, integral indicators may be difficult to interpret, especially when they include data of different natures, such as economic and environmental. This creates difficulties in identifying specific causes of changes in the integral indicator. There is also a risk of masking problems when one aspect of the system improves significantly, while another deteriorates, but the overall indicator remains stable, hiding the presence of serious problems in individual components. Furthermore, due to different calculation methodologies for integral indicators in different contexts or countries, comparing such indicators may be complicated or even incorrect. Thus, while integral indicators have important advantages in assessing complex systems, they also carry risks of loss of detail, subjectivity, and difficulties in interpretation and comparison.

In recent decades, indicators of environmental and economic efficiency of agricultural land use in Ukraine have shown generally positive dynamics. There has been a gradual increase in agricultural production, higher crop yields, higher gross harvests, etc. The results of the assessment of the economic efficiency of land use, which take into account the volume of production of basic agricultural products per 100 hectares of different types of agricultural land, reflect this well (Figures 1, 2) [1].

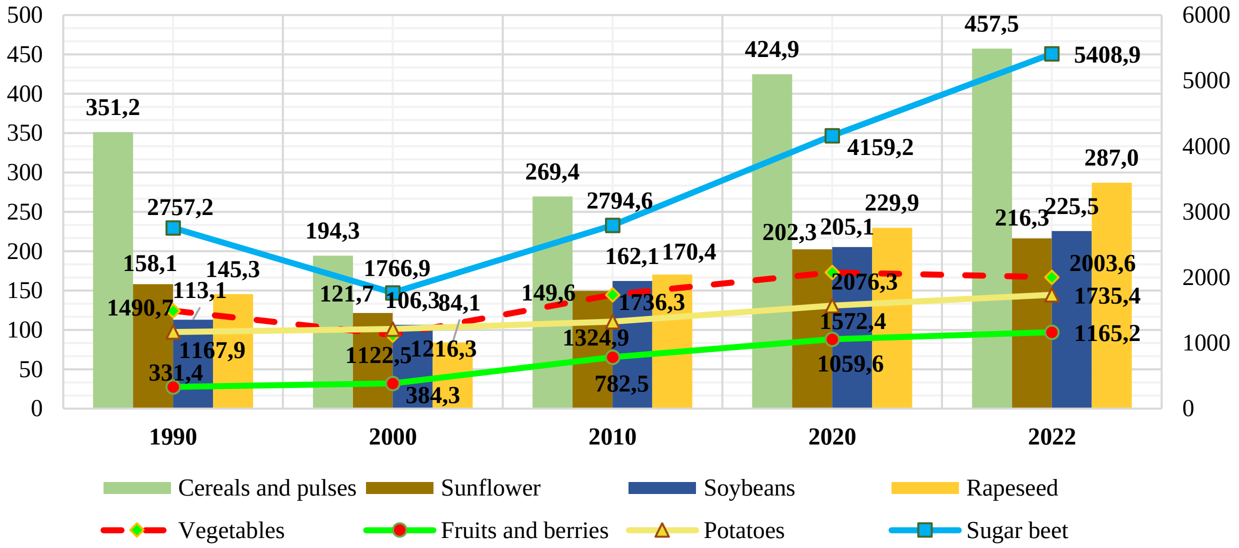

Figure 1. Crop production per 100 hectares of arable land and perennial plantations (for fruit and berry crops) in Ukraine, 1990-2022, tons [5]

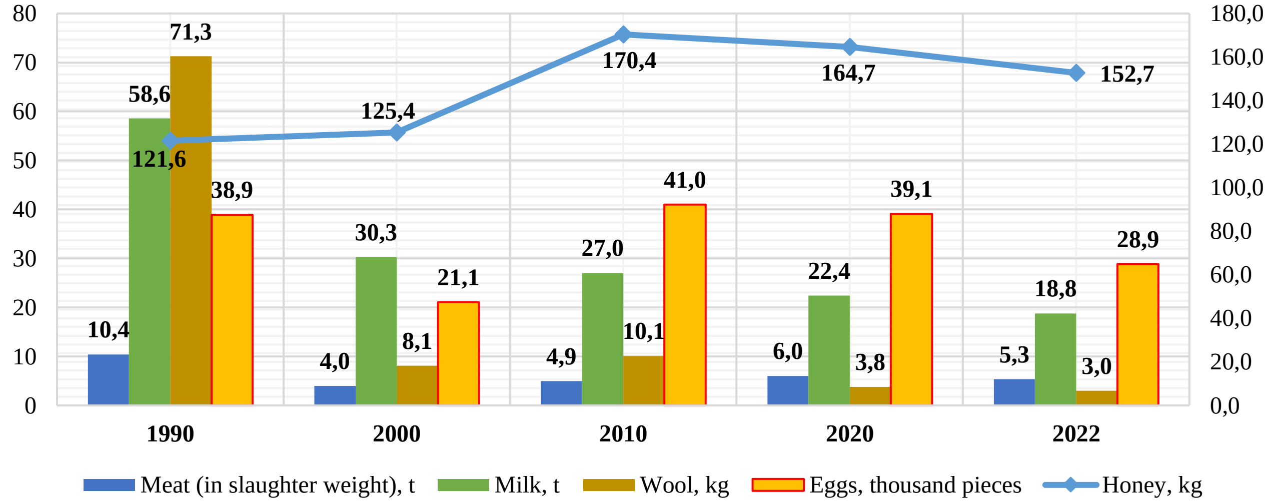

Figure 2. Livestock production per 100 hectares of agricultural land [6]

An analysis of statistical data shows (see Figure 1) that during the period from 1990 to 2000, the production volumes of all types of crop production per 100 hectares of arable land and perennial plantations (for fruit and berry crops) significantly decreased. However, in subsequent years, there was a significant increase in production, particularly in rapeseed production, which increased by almost 3.5 times, sugar beet and fruits and berries by 3 times [1].

Due to the prolonged decline in the livestock sector in Ukraine, which has been ongoing for more than 30 years since 1990, there has been a significant reduction in production: milk - by more than 3 times, meat of all types - by 2 times, wool - by more than 24 times, eggs - by almost 1.5 times (see Figure 2). The exception is a slight increase in honey production. In European countries, the volumes of livestock production are much higher. For example, in France, where agricultural land covers 30.3 million hectares, 83.5 tons of milk and 18.8 tons of meat are produced per 100 hectares [7], which is almost 10 times higher than the corresponding indicators in Ukraine. Thus, it can be concluded that the production volumes of basic agricultural products per unit area in Ukraine are insufficient.

During the years of Ukraine's independence, the main leading industries and areas of specialization of farms have significantly transformed. In the overall production of agricultural products, crop production accounts for more than 78.2%, while livestock production - for 21.8%.

Economic difficulties in the agricultural sector have affected the profitability of agricultural products. Thus, in Ukraine, from 2010 to 2022, the level of operating profitability in the sectors of agriculture, forestry, and fishing decreased from 22.9% to 20.0%. As of 01.01.2022, the highest level of profitability was in Sumy (36.4%), Luhansk (30.3%), and Kharkiv (29.7%) regions, while the lowest, with a negative value, was recorded in the Odesa region (-6.7%) (see Figure 3) [8].

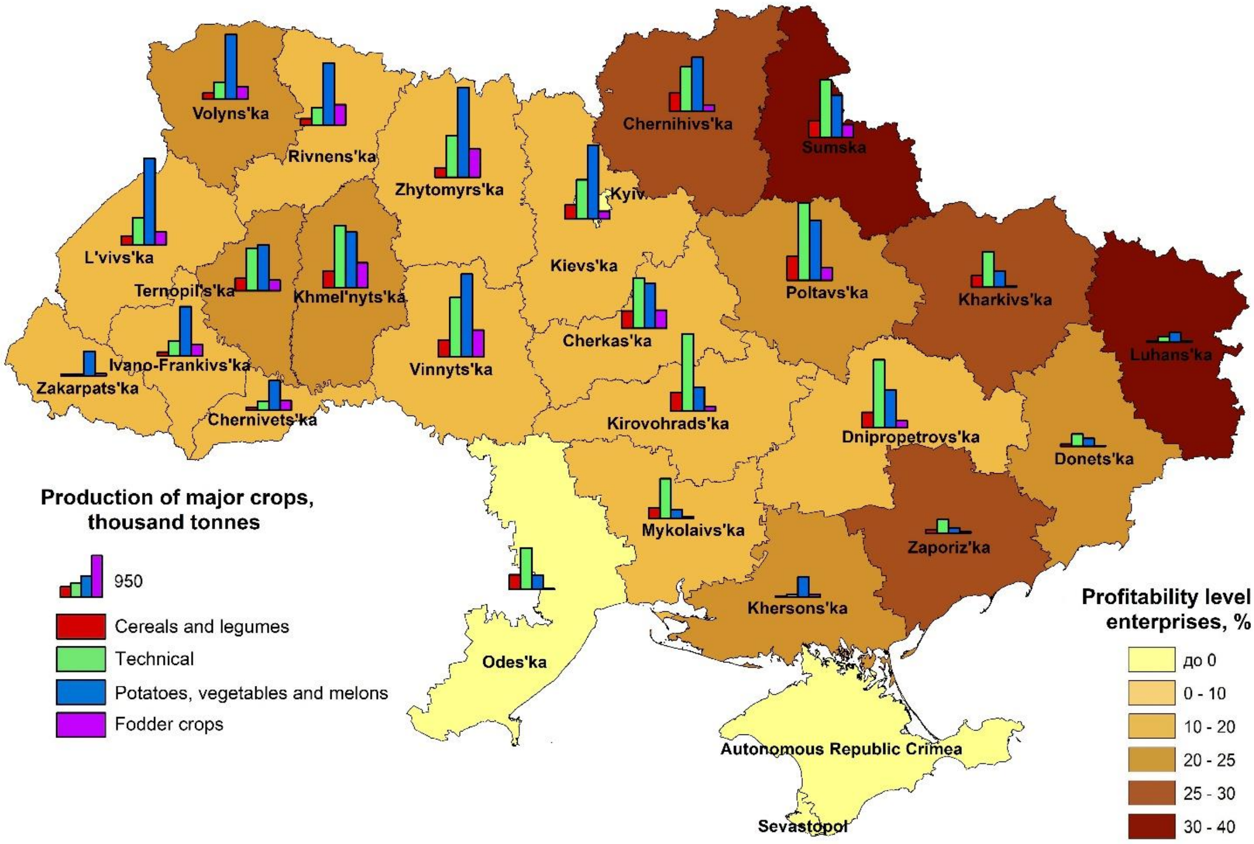

Figure 3. Agricultural production efficiency by regions of Ukraine as of 2022

It should be noted that in the early 1990s, most of the main types of agricultural products in the region's enterprises were profitable. However, now only the production of grain and leguminous crops, potatoes, some vegetables, and eggs remains profitable.

In recent years, the production structure of Ukraine's main agricultural crops has seen a trend toward reducing the production of certain technical and especially fodder crops, driven by their low profitability and market conditions [1].

Undoubtedly, after February 2022, due to the full-scale military aggression by Russia, Ukraine's agricultural sector has suffered significant losses. The war with Russia has had a significant impact on the profitability of agricultural products in agricultural enterprises, as well as on the production of agricultural crops and livestock farming. This negative impact manifests itself, in particular, through the destruction of agricultural infrastructure; destruction of crops, livestock, and farms; shortages of fuel, fertilizers, and crop protection products; loss of human resources; export and domestic market issues; increased transportation costs; price fluctuations for products and decreased purchasing power of the population; landmines in fields, loss of control over territories, etc.

Thus, military operations have a devastating impact on Ukraine's agricultural production, significantly reducing its profitability and threatening the country's food security.

The economic efficiency of agricultural land use depends on soil quality, as well as on their rational use and protection. Extensive farming methods cause the deterioration of land resources. Today, the main factors negatively affecting the environmental state of agricultural lands are degradation processes such as soil erosion by water and wind, dehumification, soil pollution, desertification, and salinization of lands. It is well known that agricultural lands are subject to a special legal regime and are subject to protection aimed at preserving their area, preventing negative soil processes, and increasing fertility through the implementation and adherence to soil protection measures [1].

Analyzing the implementation of soil protection measures, particularly the construction of anti-erosion hydraulic structures in Ukraine, it can be noted that in recent years there has been a trend towards a decrease in the volume of these works (Table 1). According to the State Geocadastre data, since 2002, the construction and reconstruction of anti-erosion hydraulic structures have been carried out: shafts, shaft-canals - 74.3 km (0.5 ha); shaft-terraces - 21.7 km; shaft-roads - 43.5 km; water discharge structures - 159 units; slope terracing - 6 units (2.8 ha); anti-erosion ponds - 47 units (586.0 ha); shore protection - 126.9 km (0.7 ha).

Moreover, as of 01.01.2024, it is necessary to construct (reconstruct) about 463 anti-erosion hydraulic structures, including 125 water discharge structures, 133 anti-erosion ponds, and 196 slope terracing structures. It is also necessary to protect lands, including agricultural land, from erosion and other adverse natural processes on a total area of 5.5 thousand hectares (see Table 1) [10].

Table 1

Construction (reconstruction) of anti-erosion hydraulic structures in Ukraine, 2012–2024*

Indicator	2012	2015	2019	2022	2024	Total since 2002	To be completed
Shafts, shaft-canals, km	2.9	0.4	8.2	0.35	–	74.3 km, 0.5 ha	3600.0 km, 1005.4 ha
Shaft-terraces, km	–	–	0.6	–	–	21.7	5767.4
Shaft-roads, km	0.2	1.6	–	0.48	–	43.5	233.2
Water discharge structures, units	8	–	1	–	–	159	125
Slope terracing, units	1.0	–	–	–	–	6 units, 2.8 ha	196
Anti-erosion ponds (solid runoff accumulators)	20 units, 6.7 ha	–	–	–	–	47 units, 586.0 ha	133 units, 3847.2 ha
Shore protection, km	7.1	0.2	5.2	–	1.39	126.9 km, 0.7 ha	464.4 km, 12 ha
Others	1 unit, 1 unit, 0.35 km2, 15.3 ha, 4 units	13.9 ha, 2 units, 0.3 km	0.07 ha, 1 unit, 0.2 km	0.07 ha, 1 unit, 1 km	0.07 ha, 1 unit	277.3 ha, 21 units, 43.0 km	644.9 ha, 9 units, 24.6 km
Ongoing construction projects	2.2 km2, 8.7 km, 1 unit, 16 units	11.6 ha, 18 units	14 units, 11.6 ha	13 units, 11.6 ha	13 units, 11.6 ha	–	–
Unfinished construction projects, units	15	15	15.0	11	10	–	–

**Source: compiled by the authors according to the State Service of Ukraine for Geodesy, Cartography and Cadastre.*

The main reason for the slow implementation of land protection measures in the regions of Ukraine is insufficient funding from both the state and local budgets.

The primary financial mechanism through which the state finances the implementation of land protection measures is compensation for losses in agricultural and forestry production. According to Article 209 of the Land Code of Ukraine, funds received as compensation for losses in agricultural and forestry production cannot be used for other purposes. Therefore, these funds are targeted revenues to the state budget, generated due to the deterioration of land quality or other actions prohibited by land legislation [1].

According to the State Geocadastre, as of 01.01.2024, 55.4 hectares of land have been withdrawn from agricultural and forestry production, of which 41.95 hectares (75.7%) were agricultural land, and 13.48 hectares (24.3%) were forest land. The total amount of funds used, received as compensation for losses in agricultural and forestry production in Ukraine, amounted to UAH 122.0 million (Table 2).

Table 2

Use of funds received as compensation for losses in agricultural and forestry production in Ukraine, 2012-2024*

Indicator	2012	2015	2019	2022	2024
Land withdrawn from agricultural and forestry production, ha	2363.07	1836.44	3042.98	3051.43	55.43
Including:					
agricultural land	2288.29	1798.22	2900.50	3000.98	41.95
forest land	74.78	38.22	142.47	50.45	13.48
Total amount accrued, thousand UAH	69222.0	93418.3	134133.4	–	–
Actual amount received to budgets of different levels, thousand UAH	94292.3	118053.6	166657.4	–	–
Total amount used, thousand UAH	96116.3	79518.7	107048.8	160798.6	122021.8
Including for:					
land development of agricultural and forestry land	1647.8	491.8	997.5	0	0
improvement of agricultural and forestry land	9042.4	14209.3	2659.3	9390.6	742.2
preparation of land management documentation for land protection	6119.2	1365.3	2480.8	773.6	1713.5
implementation of land protection measures according to the prepared documentation	22680.4	29717.0	35474.8	9970.0	290.5
implementation of normative monetary valuation of land	21598.1	13744.1	21130.9	23618.1	33345.9
land inventory	17747.5	16524.2	37206.9	35976.7	26104.7
other measures	4920.5	3467.0	7098.4	81069.7	59825.0

** Source: compiled by the authors according to the State Service of Ukraine for Geodesy, Cartography and Cadastre.*

Of this amount, only UAH 742.2 thousand (0.6%) was used for the improvement of agricultural and forestry land, UAH 1.7 million (1.4%) for the preparation of land management documentation for land protection, UAH 290.5 thousand (0.2%) for the implementation of land protection measures according to the prepared documentation, UAH 33.3 million (27.3%) for the implementation of normative monetary valuation of land, UAH 26.1 million (21.4%) for land inventory, and UAH 59.8 million (49.0%) for other measures.

Given the statistics on the receipt and use of funds received as compensation for losses in agricultural and forestry production in Ukraine during 2012-2024 (see Table 2), it should be noted that the state currently uses targeted funds intended for land protection for other measures, deviating from their original purpose.

Thus, the reform of the agricultural sector of the economy has led to significant changes in the use of agricultural land. As a result of land redistribution, de-statization, and privatization of the land fund, the agricultural land massifs were fragmented, scientifically grounded crop rotations were disrupted, and the boundaries and elements of contour-meliorative organization of the territory were lost, leading to significant soil quality deterioration and decreased agricultural production efficiency.

Furthermore, «given that the primary goal of agricultural enterprises is to maximize short-term profits, without strategic planning for the future, and that agricultural enterprises mainly use land on a leasehold basis, there is currently excessive anthropogenic pressure, environmental exhaustion of soils due to the cultivation of only highly profitable crops that bring maximum income to agribusiness» [1]. In addition, the situation with compliance with environmental requirements in agricultural land use is complicated by climate change.

Climate change is one of the most serious challenges facing modern humanity. Its impact on agriculture is already being felt, and it is expected to intensify in the coming years. This impact may lead to reduced yields, soil quality deterioration, increased risk of droughts, and other extreme weather events. Under these conditions, it is important to take measures to maintain the environmental and economic efficiency of agricultural land use. This will not only ensure food security but also preserve the environment for future generations.

Let's consider measures to support the environmental and economic efficiency of agricultural land use [9, 10, 11, 12]:

1. Introduction of Innovative Agro-technologies

Innovative agro-technologies such as precision farming, agro-robots, and genetically modified organisms (GMOs) have the potential to significantly improve the efficiency of land resource use.

The use of precision farming technologies allows for the optimization of fertilizer, water, and pesticide use, reducing costs and increasing yields by 10-30%. The economic efficiency of such systems has been proven by numerous studies, and their payback can be achieved within 3-5 years.

The use of robots for agricultural work reduces labor costs and increases production efficiency. Yields can increase by 20-25%, and labor costs can decrease by

30-40%. The payback of such investments is expected within 5-7 years.

The introduction of genetically modified crops resistant to pests and drought conditions can increase yields by 15-25% and reduce pesticide costs by 20-30%. The cost of GMO seeds is higher than traditional varieties by 10-20%, but the overall economic benefit exceeds these costs.

2. Adaptation of Agricultural Systems to Climate Change

The adaptation of agricultural systems to climate change involves the use of drought-resistant crops, the optimization of irrigation systems, and the implementation of organizational and economic measures. The use of drought-resistant crops can ensure yield stability even under unfavorable conditions. The cost of such crops is usually 5-10% higher, but the reduction of crop loss risks and yield increases by 10-15% ensures high economic efficiency.

Drip irrigation and other water-saving technologies can reduce water consumption by 30-50% and increase yields by 20-30%. The payback of such investments is achieved in 3-4 years.

Changing sowing dates, using crop rotations, and strip cropping can reduce crop loss risks and increase agro-ecosystem resilience. The cost of such measures is minimal, but their impact on yields can be significant (up to 15-20%).

3. Support for Sustainable Land Use

Sustainable agricultural development involves the use of organic farming, the implementation of agroforestry, and soil conservation measures.

The use of organic farming methods can reduce the costs of chemical fertilizers and pesticides by 20-30%, but yields may decrease by 10-15%. The economic efficiency of such systems depends on access to organic product markets, where prices are usually 20-50% higher.

Integrating shelterbelts and other protective green plantings can increase yields by 5-10% and preserve soils from degradation. Payback is achieved through increased yields and reduced erosion control costs.

Soil conservation measures, such as mulching and cover crops, can reduce soil degradation and increase soil fertility by 10-15%. The cost of such measures is low, but their long-term economic efficiency is significant.

4. Economic Incentives and Policies

To support environmental and economic efficiency, it is necessary to implement economic incentives such as subsidies and grants, green taxes, and ecosystem services markets.

State support for farmers implementing ecological farming systems can significantly increase their economic efficiency. The payback of such investments for the state is achieved through increased productivity and sustainability of the agricultural sector.

The introduction of taxes on greenhouse gas emissions can stimulate the reduction of negative environmental impacts. The effectiveness of such measures depends on the tax rate and its administration mechanisms.

The introduction of mechanisms for paying for ecosystem services can create additional incentives for preserving natural capital. The economic efficiency of such markets depends on the demand for ecosystem services and their valuation.

5. Education and Outreach Activities

Increasing awareness and education levels among farmers about the environmental and economic aspects of land use is a crucial factor for successfully implementing efficiency support measures.

Organizing training and seminars for farmers on implementing innovative agro-technologies and sustainable land use can significantly increase their efficiency. The cost of such activities is low, but their economic benefits are substantial through increased productivity and reduced costs.

Establishing advisory centers where farmers can receive professional assistance on the efficient use of land resources can enhance their economic efficiency. Disseminating information through the media and online resources about the benefits of environmentally safe farming practices and climate change adaptation measures can stimulate their adoption.

Conclusions and Prospects. To maintain the environmental and economic efficiency of agricultural land use in Ukraine, while preserving the global competitiveness of the agro-sector, a range of economic and regulatory instruments can be applied, focused on business efficiency and minimal use of prohibitions. These instruments can also be supported by quantitative assessments and indicators, allowing for more accurate evaluation of their impact and effectiveness.

Economic instruments should stimulate agricultural producers to adopt environmentally friendly technologies while simultaneously increasing their productivity and profitability. For example, subsidies and grants for the implementation of modern precision farming methods can increase yields by 10-20% per hectare while reducing fertilizer use by 15-25%. This not only enhances profitability but also reduces per hectare costs by 5-10%. Tax incentives, such as a 5-10% reduction in income tax for farmers implementing sustainable practices, can increase the adoption of such practices by 15-30%, positively impacting overall land use efficiency.

Another economic instrument is the creation of an ecological services market, where farmers can receive additional income for preserving natural ecosystems or reducing greenhouse gas emissions. For example, compensation for reducing greenhouse gas emissions can range from 10 to 20 euros per ton of CO_2 equivalent. This would allow agricultural enterprises to increase their revenues by 5-10%, depending on the scale of operations. Emissions trading can create an additional market worth hundreds of millions of hryvnias, where agribusinesses can sell their quotas for emissions reduction.

From regulatory instruments, it is worth paying attention to setting standards and norms of environmental safety, which do not burden businesses with excessive prohibitions but provide clear guidelines for environmentally responsible farming. For example, standards to minimize pesticide use may include reducing their application by 10-15% without decreasing yields, achievable through the implementation of more effective plant protection technologies. The introduction of such standards can be supported by training programs, helping farmers reduce pesticide costs by 5-10% per hectare.

Certification systems for environmentally friendly products can also become an effective tool for businesses, allowing access to premium markets. On average, prices for certified environmentally friendly products can be 20-30% higher than for regular products. This allows farmers to increase their revenues by 10-15%, even if the costs of producing such products increase by 5-7%.

At the international level, participation in global initiatives such as emissions trading programs or "carbon farming" projects can provide access to new markets and sources of financing. For example, participation in such programs can increase agricultural exports by 5-10% by reducing barriers to entry into environmentally sensitive markets in the EU or the USA. Moreover, access to "green" financial instruments can reduce capital costs for farmers by 1-2%.

These quantitative assessments and indicators allow us to see the real impact of economic and regulatory instruments on the efficiency of agribusiness, ensuring a balance between economic efficiency and environmental sustainability, emphasizing the creation of additional opportunities for businesses with minimal use of prohibitions and restrictions.

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ПІДТРИМКА ЕКОЛОГО-ЕКОНОМІЧНОЇ ЕФЕКТИВНОСТІ ВИКОРИСТАННЯ ЗЕМЕЛЬ СІЛЬСЬКОГОСПОДАРСЬКОГО ПРИЗНАЧЕННЯ В УКРАЇНІ В УМОВАХ ЗМІНИ КЛІМАТУ

Анотація. *У дослідженні розглядається питання підтримки еколого-економічної ефективності використання земель сільськогосподарського призначення в Україні в умовах зміни клімату. Зміна кліматичних умов негативно впливає на аграрний сектор, спричиняючи зниження урожайності, деградацію ґрунтів та посилення екологічних проблем. У відповідь на ці виклики дослідження зосереджене на розробці стратегій і заходів, спрямованих на забезпечення стійкого розвитку сільського господарства шляхом оптимізації використання земельних ресурсів. У роботі проведено аналіз сучасного стану земель сільськогосподарського призначення, оцінено вплив кліматичних змін на аграрну сферу, а також визначено ключові показники еколого-економічної ефективності. Запропоновані в дослідженні методи та підходи спрямовані на збереження родючості ґрунтів, зменшення екологічного впливу аграрної діяльності, підвищення економічної рентабельності та стійкості аграрного сектору. Результати дослідження можуть бути використані для вдосконалення національної політики у сфері управління земельними ресурсами та адаптації аграрного сектору до нових кліматичних реалій. Впровадження результатів дослідження може позитивно вплинути на збереження екосистем, підвищення економічної ефективності аграрного сектору та покращення добробуту сільського населення в Україні. Таким чином, дослідження робить вагомий внесок у розвиток наукових знань та практик щодо ефективного використання земельних ресурсів в умовах глобальних кліматичних змін.*

Ключові слова: *земельні ресурси, ефективність використання земель сільськогосподарського призначення, продовольча безпека, зміна клімату,*

екологічно безпечне землекористування, охорона земель, протиерозійні гідротехнічні споруди.