

THE BIOECONOMIC BASIS OF POST-WAR RECOVERY OF RURAL ECONOMY

© 2025 PETRUKHA N. M., PETRUKHA S. V., UMANETS Ye. M., RYBITSKYI O. L.

UDC 338.43
JEL Classification: Q10; Q11; Q18; Q19

Petrukha N. M., Petrukha S. V., Umanets Ye. M., Rybitskyi O. L.
The Bioeconomic Basis of Post-War Recovery of Rural Economy

The article analyzes the role of bioeconomy as a basis for the recovery of Ukraine's rural economy in the post-war period. Based on the conducted analysis, it is determined that despite the losses resulting from the ongoing war, the agrarian sector retains a significant share in global grain production; however, infrastructure damage, land pollution, and disruptions in logistics chains complicate recovery. It is indicated that the post-war recovery of Ukraine's rural economy requires the implementation of bioeconomic approaches, particularly through the integration of modern biotechnologies and the restoration of land resources. It is also determined that the Strategy for the Development of Agriculture and Rural Areas of Ukraine until 2030 is aimed at increasing the efficiency of the agricultural sector, developing competitive production, and ensuring the sustainable development of rural areas. Therefore, the effective use of water resources, support for organic production, and the development of the legislative framework are necessary steps to ensure the sustainable development of agricultural production in the context of armed conflict. A spatial analysis of organic lands in Ukraine has shown significant regional differentiation, which requires the development of regional policies to support organic production, taking into account local conditions and needs. It is found that the post-war recovery of Ukraine's rural economy requires a comprehensive approach that includes the implementation of the principles of both bioeconomy and circular economy. It is further determined that the European Bioeconomy Strategy, which focuses on sustainability, circularity, and the rational use of natural resources, is of great importance for the recovery of war-affected regions of Ukraine, especially in the context of using bioresource technologies. It is also found that the key directions of the strategy are the modernization of agriculture through bio-oriented technologies, the development of local bioeconomies that stimulate job creation, and the effective management of agricultural waste, particularly through composting and reducing food waste, which will help decrease environmental impact and improve soil fertility.

Keywords: bioeconomy, rural economy, agrarian sector, post-war recovery, agrarian policy, Strategy for the Development of Agriculture and Rural Areas in Ukraine.

Fig.: 5. Tabl.: 1. Bibl.: 18.

Petrukha Nina M. – Candidate of Sciences (Economics), Associate Professor, Associate Professor of the Department of Management in Construction, Kyiv National University of Construction and Architecture (31 Povitryanykh Syl Ave., Kyiv, 03680, Ukraine)

E-mail: nninna1983@gmail.com

ORCID: <https://orcid.org/0000-0002-3805-2215>

Researcher ID: <https://www.webofscience.com/wos/author/record/2411439>

Scopus Author ID: <https://www.scopus.com/authid/detail.uri?authorId=58000960900>

Petrukha Serhii V. – Candidate of Sciences (Economics), Associate Professor, Associate Professor of the Department of Management in Construction, Kyiv National University of Construction and Architecture (31 Povitryanykh Syl Ave., Kyiv, 03680, Ukraine)

E-mail: psv03051984@gmail.com

ORCID: <https://orcid.org/0000-0002-8859-0724>

Researcher ID: <https://www.webofscience.com/wos/author/record/2411435>

Scopus Author ID: <https://www.scopus.com/authid/detail.uri?authorId=57006812300>

Umanets Yevhen M. – Postgraduate Student, College of International Business (1 Duchnovic Square, Preshov, 08001, Slovakia)

E-mail: Jekaum@ukr.net

Rybitskyi Oleksandr L. – Postgraduate Student, National Scientific Center "Institute of Agricultural Economics" (10 Heroiv Oborony Str., Kyiv, 03680, Ukraine)

E-mail: arybitskiy@gmail.com

УДК 338.43
JEL Classification: Q10; Q11; Q18; Q19

**Петруха Н. М., Петруха С. В., Уманець Є. М., Рибіцький О. Л. Біоекономічна основа повоєнного відновлення
сільської економіки**

У статті аналізується роль біоекономіки як основи для відновлення сільської економіки України в післявоєнний період. На основі проведеного аналізу визначено, що, незважаючи на втрати від війни, аграрний сектор зберігає значну частку у світовому виробництві зернових, хоча пошкодження інфраструктури, забруднення земель і порушення логістичних ланцюгів ускладнюють відновлення. Визначено, що повоєнне відновлення сільської економіки України потребує впровадження біоекономічних підходів, зокрема через інтеграцію сучасних біотехнологій, та відновлення земельних ресурсів. Визначено, що Стратегія розвитку сільського господарства та сільських територій України до 2030 року спрямована на підвищення ефективності аграрного сектора, розвиток конкурентоспроможних виробництв і сталий розвиток сільських територій, однак ефективне використання водних ресурсів, підтримка органічного виробництва та розвиток законодавчої бази є необхідними кроками для забезпечення сталого розвитку сільськогосподарського виробництва в умовах воєнного конфлікту. Просторовий аналіз органічних земель в Укра-

їні показав значну регіональну диференціацію, що вимагає розробки регіональної політики підтримки органічного виробництва з урахуванням місцевих умов і потреб. Установлено, що повоєнне відновлення сільської економіки України потребує комплексного підходу, що включає впровадження принципів біоекономіки та циркулярної економіки. Визначено, що Стратегія біоекономіки Європи, яка зосереджена на сталості, циркулярності та раціональному використанні природних ресурсів, має велике значення для відновлення постраждалих від війни регіонів України, особливо в контексті використання біоресурсних технологій. Встановлено, що ключовими напрямками стратегії є модернізація сільського господарства через біоорієнтовані технології, розвиток локальних біоекономік, що стимулює створення нових робочих місць, а також ефективне управління сільськогосподарськими відходами, зокрема через компостування та зменшення харчових відходів, що допоможе знизити екологічне навантаження та поліпшити родючість ґрунтів.

Ключові слова: біоекономіка, сільська економіка, аграрний сектор, повоєнне відведення, аграрна політика, Стратегія розвитку сільського господарства та сільських територій в Україні.

Рис.: 5. Табл.: 1. Бібл.: 18.

Петруха Ніна Миколаївна – кандидат економічних наук, доцент, доцент кафедри менеджменту в будівництві, Київський національний університет будівництва і архітектури (просп. Повітряних Сил, 31, Київ, 03680, Україна)

E-mail: nninna1983@gmail.com

ORCID: <https://orcid.org/0000-0002-3805-2215>

Researcher ID: <https://www.webofscience.com/wos/author/record/2411439>

Scopus Author ID: <https://www.scopus.com/authid/detail.uri?authorId=58000960900>

Петруха Сергій Валерійович – кандидат економічних наук, доцент, доцент кафедри менеджменту в будівництві, Київський національний університет будівництва і архітектури (просп. Повітряних Сил, 31, Київ, 03680, Україна)

E-mail: psv03051984@gmail.com

ORCID: <https://orcid.org/0000-0002-8859-0724>

Researcher ID: <https://www.webofscience.com/wos/author/record/2411435>

Scopus Author ID: <https://www.scopus.com/authid/detail.uri?authorId=57006812300>

Уманець Євген Миколайович – аспірант, Вища школа міжнародного бізнесу (площа Духновича, 1, Пряшів, 08001, Словаччина)

E-mail: Jekaum@ukr.net

Рибіцький Олександр Леонідович – аспірант, Національний науковий центр «Інститут аграрної економіки» (вул. Героїв Оборони, 10, Київ, 03680, Україна)

E-mail: arybitskiy@gmail.com

Agriculture is one of the key components of Ukraine's economy, ensuring not only food security but also a significant portion of the State's export revenues. However, the full-scale war that is ongoing since 2022 has caused serious damage to the agricultural sector, necessitating its urgent recovery. The post-war restoration of the rural economy should be based on new principles, focusing on sustainable development, innovation, and the efficient use of biological resources, which are the foundation of the bioeconomy.

Bioeconomy presents a new approach to agriculture, focused on the circular economy, sustainable development, and the conservation of natural resources. It aims to maximize the use of biological resources, such as agricultural production waste, to create new productive opportunities, which can significantly enhance the efficiency of the agricultural sector in the post-war recovery period. The recovery of the rural economy, considering innovative bioeconomic approaches, will not only be a path to economic growth but also to achieving environmental sustainability and preserving biodiversity.

In this regard, we see the necessity of conducting an analysis of the bioeconomic basis for the post-war recovery of the rural economy, as the application of bioeconomic principles in agriculture will not only

restore production capacities but also create new opportunities for growth and the integration of Ukraine into the global agrarian market based on sustainable development and efficient use of natural resources.

Analysis of recent research and publications.

Recent studies in the field of bioeconomy and waste management in Ukraine's agrarian sector demonstrate the importance of integrating sustainable practices into the post-war economic recovery. They focus on the processing of agricultural production waste, which opens up new opportunities for economic growth and increased efficiency in the agri-sector. Research by L. Karbovska, Y. Mazur, K. Zheleznyak, et al. [5], focuses on the formation of an effective waste management system in Ukraine's agrarian sector, which is an important part of the bioeconomic development strategy. According to these studies, the application of organizational and financial tools is crucial for ensuring effective waste management and recycling. Thus, contemporary publications emphasize the importance of transitioning to a circular economy and sustainable technologies for the recovery of Ukraine's agrarian sector after the war.

Formulation of the article's aims. The aim of the article is to survey the role of bioeconomy as the basis for the post-war recovery of Ukraine's rural economy, to identify strategic directions for the use of

biological resources for the sustainable development of the agrarian sector, and to analyze the possibilities of implementing the principles of circular economy and sustainable natural resource management in the context of rural area recovery.

Presentation of the main material of the research. The agrarian sector of Ukraine has strategic importance not only for ensuring national food security but also for the stability of global food markets. Due to the military aggression of the Russian Federation, the agricultural sector has become one of the main elements of national security to ensure the stability of both the Ukrainian State and international trade relations. According to the State Statistics Service of Ukraine, in 2024, despite fluctuations, a GDP growth of 2.9% indicates an economic recovery, where the main drivers of growth were the construction, finance, and transport sectors, while agriculture and trade experienced a decline [1; 2]. Moreover, nearly 30% of the country's population lives in rural areas, and a significant portion of employed citizens work in the agrarian sector, making agriculture a key factor in socioeconomic development.

According to statistical data, Ukraine demonstrates high self-sufficiency in food production: over 90% of meat products, bread, oils, and other food items are produced directly within the country. Ukraine holds a significant share in the global production of products such as sunflower oil, barley, wheat, corn, and sugar, making it a key player in the global food market [12]. In particular, an analysis of export indicators for grains, legumes, and flour for the 2024/2025 marketing year, according to the State Customs Service of Ukraine, shows a certain trend towards a decrease in export volumes. The total export volume of grains and flour amounts to 33.089 thousand tons, which is a decrease compared to the previous year (36.135 thousand tons). Wheat exports, which in the 2024/2025 marketing year amounted to 13.254 thousand tons, are somewhat lower compared to 14.228 thousand tons in the 2023/2024 marketing year. A decrease is also observed in corn exports – 17.061 thousand tons in the current year compared to 19.533 thousand tons in the previous year. At the same time, barley exports during this period increased from 1.973 thousand tons to 2.213 thousand tons, indicating positive dynamics in certain segments. Regarding flour exports, there is a slight increase in the volume of wheat flour exports, which rose from 50.2 thousand tons to 54.1 thousand tons. Along with this, the total volume of flour exports, in grain equivalent, decreased from 107.7 thousand tons in the 2023/2024 marketing year to 80.8 thousand tons in the 2024/2025 marketing year. This trend indicates a general decrease in the

volume of grain and processed grain product exports, which may be due to both internal economic factors and changes in international markets (Fig. 1) [6].

It is worth noting that the ongoing war has significantly complicated the situation in the agrarian sector: damage to infrastructure, land contamination, mined territories, and the destruction of agricultural enterprises have become serious challenges for the country's economic recovery. As a result of military actions, logistics chains have been disrupted, and the production and export volumes of key agrarian products have decreased. The deterioration of the food situation, rising prices, and declining purchasing power of the population lead to significant social problems, particularly to a lack of access to food in low-income conditions, especially in rural areas.

Over the past few decades, Ukraine has experienced a decrease in livestock production, which has led to a significant change in the structure of agricultural production. The production of grain crops increased by 2.2 times from 1991 to 2021, while the production of meat and milk has significantly decreased. This process, combined with low levels of agricultural raw material processing and the absence of innovative technologies, negatively affects the overall productivity of the agricultural sector. Despite these difficulties, the agrarian sector has the potential for recovery thanks to the active development of small and medium enterprises, which provide a significant portion of jobs and contribute to the development of the regional economy. With effective support for these enterprises, as well as the introduction of innovations and modern technologies, Ukraine can restore its status as one of the leading food suppliers in international markets.

In this regard, we consider it important to note that the post-war recovery of Ukraine's rural economy should be based on sustainable bioeconomic approaches, which include the integration of modern biotechnologies, the restoration of land resources, and investments in the development of small and medium-sized enterprises. To ensure the effective use of natural resources, stimulate agricultural production, and promote the growth of added value through the processing of agricultural products, the Strategy for the Development of Agriculture and Rural Areas in Ukraine for the period up to 2030 was approved as part of the implementation of strategic directions for the development of the agrarian sector and rural areas of Ukraine, based on the order of the Cabinet of Ministers of Ukraine dated November 15, 2024, No. 1163-p [12]. This regulatory act defines the main priorities and mechanisms for implementing the State policy in the field of agriculture, contributing to sustainable economic development, improving the level

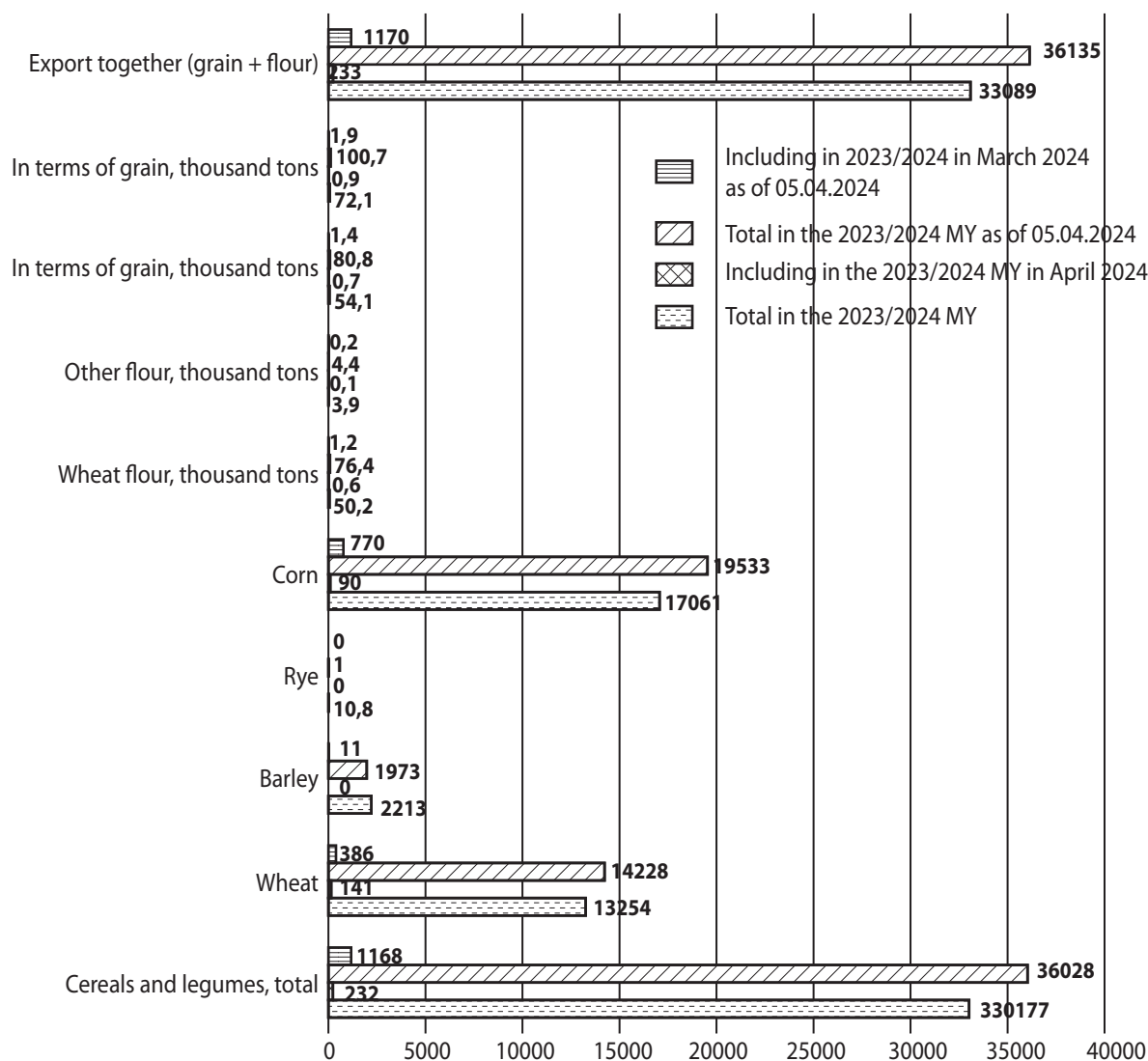


Fig. 1. Exports of grains, legumes (and their processed products), and flour from Ukraine for the 2024/2025 marketing year, in thousand tons as of 04.04.2025

Source: [6].

of social and infrastructural provision of rural areas, and stimulating the introduction of innovative technologies. The strategy is directed towards improving the living conditions of the rural population, efficient use of natural resources, development of competitive agrarian production, and integration of modern technological solutions to achieve sustainable development of rural areas in the long term.

The *Tbl. 1* reflects the strategic goals and indicators that define the development of agriculture and rural areas in Ukraine until 2030, which includes the main directions of State policy that contribute to increasing the efficiency of the agrarian sector, meeting public needs for food products, ensuring the sustainability of the agricultural sector, efficient land use, the development of climate-oriented agriculture, the modernization of the agrarian sector, and the development of rural areas. The indicators characterizing the

dynamics of measures in the short-term (2025–2026) and medium-term (2027–2030) perspectives are considered separately.

Post-war recovery of Ukraine's rural economy is impossible without reforming the water resource management system, particularly by reducing subsidies for water supply in agriculture. It is worth noting that this aspect will increase the efficiency of water use, contributing to achieving high results in organic production. Organic production, which is more costly compared to traditional methods, plays a key role in ensuring sustainable agricultural development and environmental protection. However, limited financial resources in wartime conditions lead to a significant number of agricultural producers abandoning organic production, especially in crop and livestock farming.

Table 1

**The forecast indicators for achieving strategic goals in the development of agriculture
and rural areas of Ukraine by 2030**

Strategic goal	Indicator	Measuring units	BV	2025	2026	2027–2030
Goal 1: Formation of the State policy for agricultural development	The share of farms that participated in government support programs	%	11 (2023)	30–40	50	–
	The share of farms that participated in international aid programs	%	25 (2024)	40–50	50	–
	The share of EU programs	%	90 (2024)	90	90	90
Goal 2: Satisfaction of public needs for food products	The share of food costs in consumer spending	%	53,8 (2024)	53,1–51,5	2,7–9,1	2,1–9,5
	Differentiation of meat consumption	times	2 (2024)	2	2	1,8
	Differentiation of milk consumption	times	2,2 (2024)	2,2	2,2	2,2
	Differentiation of fruit consumption	times	2,6 (2024)	2,6	2,6	2,3
Goal 3: Ensuring the resilience of the agricultural sector	Labor productivity in agriculture	USD thousand	18,6 (2021)	19,5	21	23
	The share of profitable enterprises (agriculture)	%	78,5 (2023)	83	88	95
	The share of profitable enterprises (livestock)	%	72,4 (2023)	73	78	85
	The share of profitable enterprises (food industry)	%	72,3 (2023)	73	75	78
Goal 4: Efficient land use	The share of returned land in cultivation	%	–	5,8	17,4	–
	The share of agricultural land in circulation	%	0,6 (2024)	0,64	0,69	1
	The area of land leased through Prozorro	thousand ha	69 (2024)	74	79	104
Goal 5: Climate-oriented agriculture	The share of organic agricultural land	%	0,6 (2022)	0,65	0,7	3
	The volume of disposed agricultural waste	%	23 (2020)	45,2	60	–
	The volume of disposed food waste	%	79 (2020)	80	85	–
Goal 6: Modernization of the agrarian sector	The share of capital investments in intangible assets (agriculture)	%	2,1 (2022)	3	5	–
	The share of capital investments in intangible assets (food industry)	%	3 (2022)	3	5	–
	Volumes of processed agricultural raw materials	million tons	20,1	22	38,8	–
Goal 7: Development of rural areas	Employment level in rural areas	%	53,6 (2021)	54,4	56,6	65,6
	Differentiation of wages (city/village)	times	1,5 (2021)	1,5	1,48	1,2

Note: BV – basic value.

Source: [12].

The mechanism of the State support for organic production is enshrined in the Law of Ukraine «On the Basic Principles and Requirements for Organic Production, Circulation and Labeling of Organic Products» [11]. However, the reduction of government funding due to the military aggression of the Russian Federation against Ukraine threatens the further development of the organic sector. To support organic production, it is necessary to continue improving the legislative framework and adapting to European standards, which contributes to Ukraine's integration into the European Union [12].

According to the data presented on the «Organic Map of Ukraine» as of December 31, 2023 (Fig. 2), the total area of agricultural land in organic and in-conversion status amounts to 149,191 hectares, of which 77,463 ha are certified organic areas, and 71,728 ha are the in-conversion lands. These data indicate a consistent trend towards the development of organic production in the agricultural sector of Ukraine, despite the challenging socioeconomic situation, ongoing war, and foreign policy challenges.

An analysis of regional differentiation allows for the identification of areas with the highest level of organic farming development. These include, in particular, Zhytomyr region (24,918 ha), Poltava region (17,286 ha), Rivne region (7,852 ha), Volyn region (4,919 ha), and Kyiv region (3,099 ha). A characteristic feature of these regions is the presence of favorable soil and climatic conditions, a high level of investment activity, as well as the development of export-oriented agrarian infrastructure, which contributes to the introduction of organic farming technologies.

At the same time, in certain eastern regions – specifically Donetsk, Luhansk, Kherson, Kharkiv, Dnipropetrovsk, Zaporizhzhia, Mykolaiv, Kirovohrad, and Sumy – there is a lack of organic land or its level is quite low, which is primarily due to the effects of armed conflict, the occupation of certain territories by the enemy, the lack of access to appropriate infrastructure, and a significant level of risks for agricultural producers.

In the western regions, such as Lviv, Ivano-Frankivsk, Ternopil, Zakarpattia, and Chernivtsi regions, a moderate level of organic production development is observed (from 0 to 2,027 ha), which is explained by the predominance of small-scale agricultural production, limited areas of arable land, a high proportion of mountainous and foothill territories, as well as a relatively low level of investment in the development of organic infrastructure and certification processes.

Overall, a spatial analysis provides grounds to assert the presence of a distinct regional asymmetry in the distribution of organic lands, indicating the unevenness of institutional, infrastructural, and financial

support for the implementation of organic farming at the national level. Such differences necessitate the development of targeted regional policies to support the organic sector, taking into account the natural-economic and sociopolitical characteristics of each region.

The results of the spatial analysis confirm the significant potential for the development of organic production in Ukraine, which, however, remains partially unrealized due to military actions, insufficient coordination of the State support for agricultural producers, and limited access to financial resources for small and medium-sized producers [7].

Despite these challenges, Ukraine has the opportunity to take advantage of international initiatives aimed at developing sustainable agricultural production, particularly the European Bioeconomy Strategy [16], which is focused on ensuring food security, sustainable management of natural resources, and reducing dependence on non-renewable resources, where these goals are closely linked to the «European Green Deal» initiatives and the development of a circular bioeconomy [12].

The most important principles of the EU bioeconomy strategy are based on sustainability and circularity. This means that the bioeconomy must operate within environmentally safe limits, supporting biodiversity and reducing the ecological footprint. In the context of restoring rural economies after the war, it is important not only to restore production capacities but also to apply the principles of the circular economy for the efficient use of natural resources, particularly land and water, which is especially important for ensuring food security and sustainable development in post-conflict areas.

Also, it is worth noting that the rural economy requires not only the restoration of physical infrastructure but also a transition to new, sustainable production models. The role of bioeconomy in this process lies in the development of bioresource technologies, which can become the basis for the recovery of affected regions. In this regard, it is important to highlight that the bioeconomy strategy in the context of post-war recovery should include the following key directions:

1. Modernization of agricultural production through the use of bio-oriented technologies that reduce environmental impact and increase the efficiency of natural resource use.
2. The development of local bioeconomies, which contributes to the restoration of local production chains, the creation of new jobs, and the reduction of unemployment in post-conflict regions.

ОРГАНІЧНА КАРТА УКРАЇНИ

СТАНOM НА 31.12.2023 РОКУ

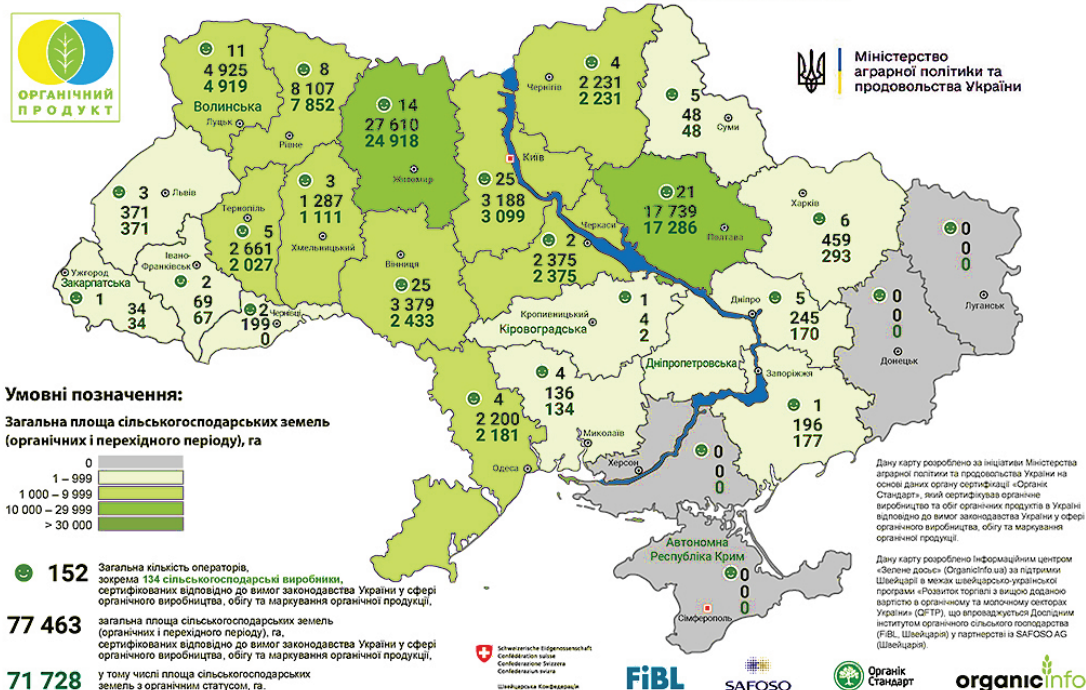


Fig. 2. Organic map of Ukraine as of 31.12.2023

Source: [7].

- Support for bioresource infrastructure, particularly the establishment and improvement of bioresource enterprises capable of restoring the production of energy, feed, and bioproducts.

For Ukraine, which is experiencing a difficult period of post-war recovery, it is important to pay attention to the opportunities that bioeconomy offers for the restoration of the rural economy. Given the rich natural resources and the traditional significance of agriculture, bioeconomy can become a key tool in the post-conflict recovery period. Moreover, the development of a bioeconomy strategy at the national level can serve as a basis for integrating Ukraine into European economic and environmental processes.

Bioeconomy, as a strategic direction of EU policy, has immense potential for the recovery of the rural economy. The implementation of bioeconomic principles focused on sustainable development, circularity, and the rational use of biological resources is critical for achieving not only environmental but also economic recovery goals. Considering the EU's experience, it can be asserted that bioeconomy should become the basis for building a sustainable and highly efficient rural economy in Ukraine in the context of post-conflict recovery [16].

For Ukraine, the introduction of a circular bioeconomy is a strategically important task that includes the processing of renewable resources, reducing energy and natural resource costs, and ensuring environmental safety. Promising directions for the agrarian sector include:

- Formation of integration links between agricultural producers and the processing industry to create cyclical value chains.
- Stimulating innovative and technological development and integrating the processing industry into global value chains.
- Government support for the implementation of resource-efficient technologies, as well as the development of digital technologies to improve the management and tracking of food products in the value chain.

It is worth noting that these steps in the Strategy for the Development of Agriculture and Rural Areas in Ukraine for the period up to 2030 will significantly improve resource use and reduce the negative impact on the environment. One of the key areas supporting these initiatives is the development of a circular bioeconomy, which is aimed at efficient resource use and minimizing environmental impact.

The circular bioeconomy aims to reduce food waste, which is an important component of sustainable consumption and production. In Ukraine, measures are being taken in accordance with the Law «On Waste Management» to promote sustainable production, increase resource efficiency, and reduce waste volumes. Special attention is given to reducing food waste in retail networks and catering establishments [12].

Managing agricultural waste is an important component of the sustainable development strategy for agriculture, as it helps reduce the negative impact on the environment and ensures the rational use of resources. The main goal of waste management is to prevent soil and water pollution, reduce greenhouse gas emissions, and minimize risks to human and animal health. In this regard, Ukraine has observed certain dynamics in the management of agricultural production waste, which includes recycling, incineration, and disposal of waste in specially designated areas. In recent years, the disposal of agricultural waste has consistently remained at a high level, indicating a positive trend in the management of this waste. Specifically, in 2023, the proportion of disposed waste was 85.03%, which is the highest figure over the entire observation period (Fig. 3).

Technological processes used for the disposal of agricultural production waste should be oriented towards the efficient processing of residues, which allows for the reduction of environmental risks and provides additional resources for agricultural production. One of the most efficient methods of processing organic waste is composting, which contributes to the enrichment of soils with organic matter, improves their structure and moisture retention capacity, which is crucial for the sustainable development of agriculture in the context of climate change. This approach to waste management not only aligns with the principles of the circular economy but also creates potential for the development of the bioeconomy, being an important factor for the post-war recovery of the rural economy in Ukraine [9; 15].

In the practice of many foreign countries, various organic waste composting systems are used, ranging from small-scale home (garden) composters to large industrial complexes. The European Compost Network unites 72 associated members from 27 European Union countries, serving over 3000 enterprises and promoting the development and spread of this technology in large production facilities [18]. Yet, in Ukraine, the share of organic waste composting in agriculture remains very low, at only 0.1%, and the process of organic waste fermentation occupies a negligible share, ranging from 0.9% to 1.2% of the total waste management volume [4].

The main reasons for inefficient waste management in the agricultural sector are underfunding of the environmental protection sector and limited investments in environmental initiatives in agricultural production. Environmental expenditures should be directed towards preventing pollution, mitigating the consequences of the negative impact of economic activities on the environment, and preserving biodiversity [3]. According to current legislation [13], the responsibilities of local self-government bodies (hereinafter referred to as LSG bodies) regarding the separate collection of waste and the achievement of target indicators for the preparation of household waste for reuse and recycling cannot be implemented without an appropriate financial mechanism to cover the costs of organizing such collection by packaging producers. Currently, all costs are covered by local budgets, which makes the effective implementation of the separate collection system impossible without appropriate funding. In European countries, the separate waste collection system functions only thanks to the financial support of companies that are obliged to finance the infrastructure for this process [14].

According to the respective legislation, the financing of waste management activities must be carried out at the expense of waste producers and owners. For this purpose, the use of funds from the State and local budgets, environmental protection funds, voluntary contributions from enterprises and citizens, as well as other sources not prohibited by law is provided [13]. The Fig. 4 shows the dynamics and volume of capital investments in environmental protection in areas such as waste management, protection and rehabilitation of soil, groundwater and surface water. As the figure indicates, there is currently instability in the funding of environmental protection measures, as well as a lack of clear allocation of funds among different areas. In particular, for the «waste management» area, during the studied period, these measures received between 11.7% and 35.4% of the total volume of investments in environmental protection, while for «soil protection and rehabilitation» it was between 9.8% and 19.3% (Fig. 4).

The total volume of capital investments in agriculture for environmental purposes demonstrates high volatility, while the proportion of expenditures directly on waste management remains insignificant in the financing structure: 4.4% in 2019, 4.1% in 2020, 3.9% in 2021, 0.6% in 2022, and 1.1% in 2023 (Fig. 5). This imbalance indicates a fragmented approach to forming the institutional system for the disposal and recycling of agricultural production waste. Instead, a significant portion of investments (from 30% to 85% in different years) was directed to-

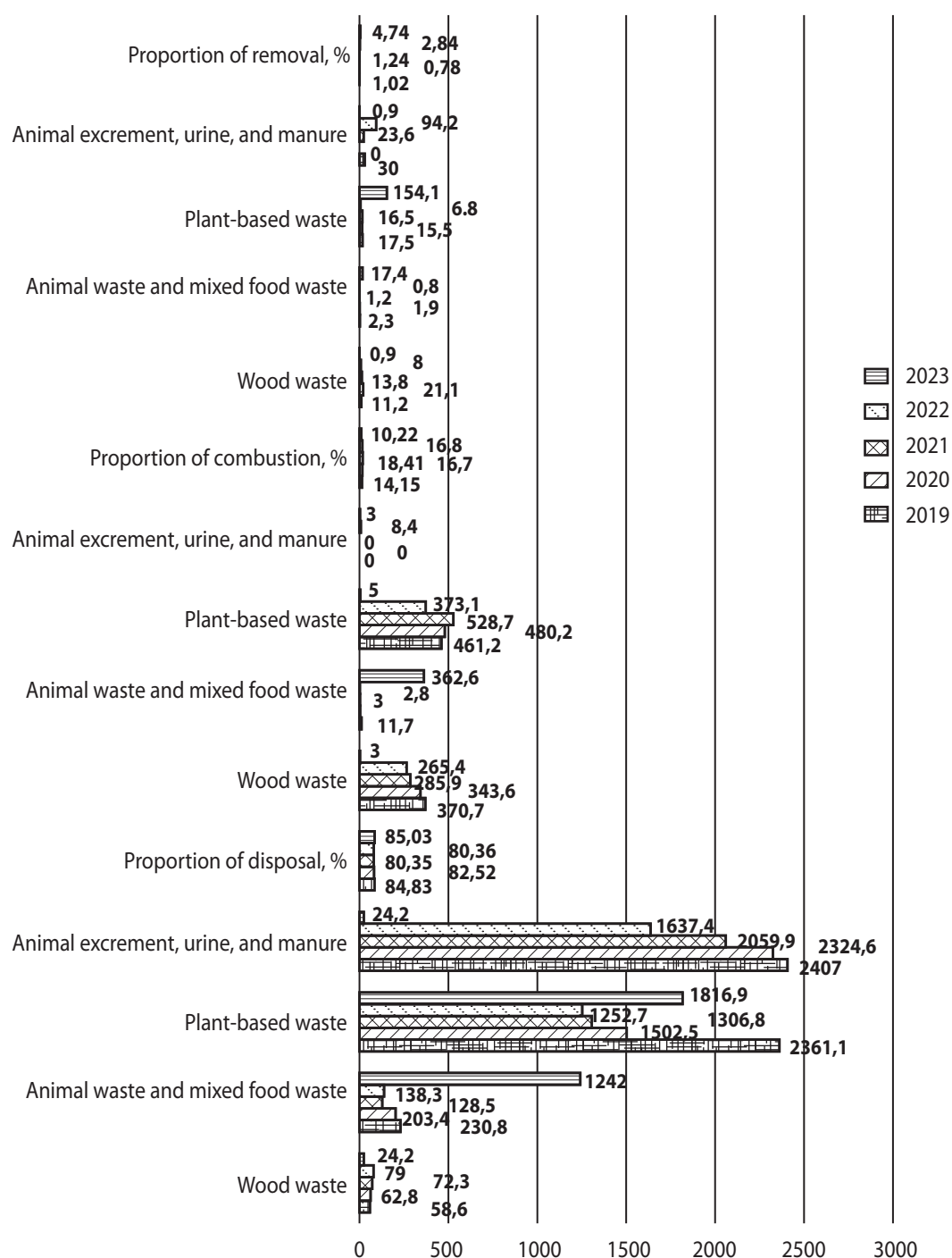


Fig. 3. Main methods of agricultural waste management in Ukraine during 2019-2023 (thousand tons)

Source: developed by the authors on the basis of the source [3; 8-10].

wards the implementation of other environmental measures, particularly related to ensuring radiation safety, conducting scientific research, or unidentified expenditures, which complicates the systematic modernization of agro-waste management infrastructure. The lack of stable funding for priority waste management areas also indicates institutional shortcomings in this segment of the State's ecological policy.

Despite the mentioned problems, the legislative initiative implemented within the framework of European approaches to waste management laid the founda-

tion for the gradual reform of this sector. In particular, as of July 9, 2023, the Law of Ukraine «On Waste Management», adopted in December 2022, came into force, which significantly modernized the regulatory framework in accordance with the requirements of European Union directives [13]. This legislative act significantly expanded the functional powers of the LSG bodies, particularly in terms of organizing the collection, transportation, processing, and disposal of household waste. Such decentralization of managerial decisions is an important prerequisite for the forma-

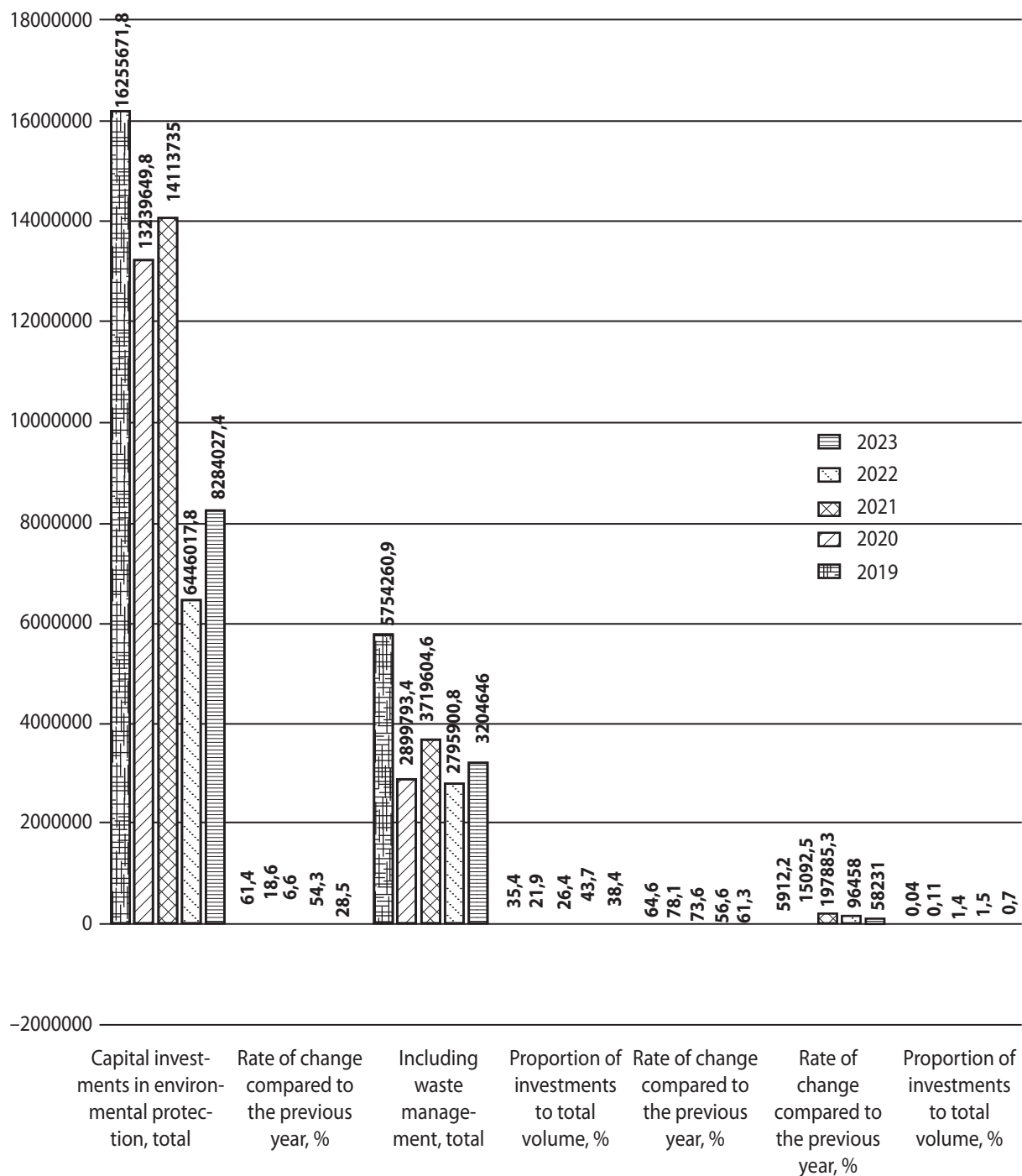


Fig. 4. The dynamics of capital investment volumes in the sphere of environmental protection, waste management, and agricultural production in Ukraine in 2019–2023, UAH million

Source: developed by the authors on the basis of the source: [3; 8–10].

tion of an integrated waste management system in the agri-sector.

In this context, the necessity of building a multi-level management system is emphasized, which should encompass four key levels: State, municipal, corporate (agricultural enterprises), and individual (consumers). This will ensure the implementation of the main directions of efficient agricultural waste management, among which the following should be highlighted:

- ✦ prevention of waste generation in the agricultural production process;
- ✦ preliminary sorting and classification of agricultural waste by material characteristics;
- ✦ ensuring compliance with environmental standards in waste management;
- ✦ financial support for the implementation of environmental protection measures in the field of agrarian production;

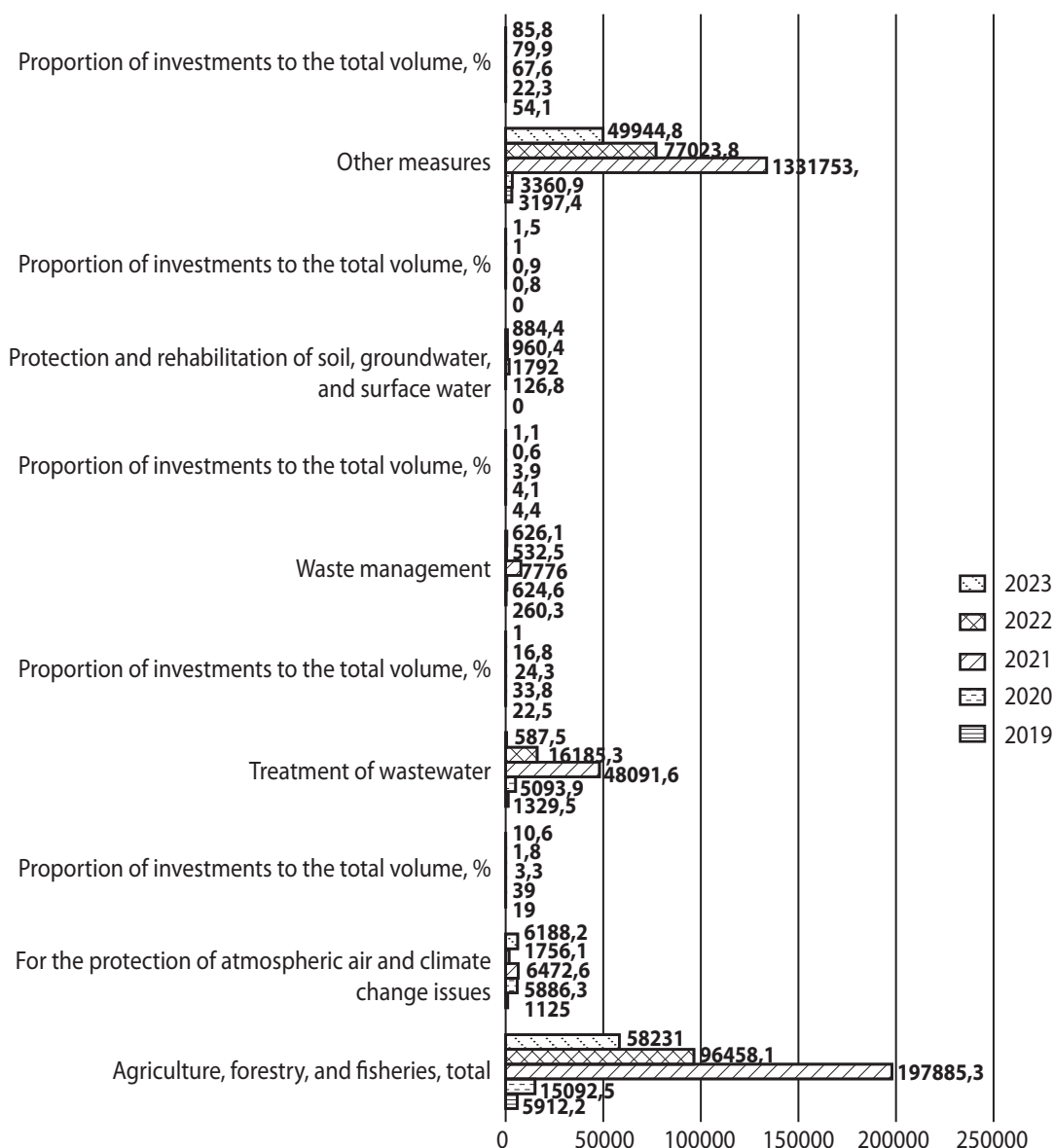


Fig. 5. The structural dynamics of capital investments in environmental protection measures in the agricultural sector of Ukraine for the years 2019–2023, UAH thousand

Source: developed by the authors on the basis of the source: [3; 8–10].

- ✦ strengthening institutional control over compliance with waste legislation;
- ✦ formation of ecological culture and behavior among the rural population;
- ✦ timely disposal and recycling of agricultural waste.

Thus, the systematic renewal of agricultural waste management policies in the context of post-war rural economic recovery should be based on the principles of the circular economy, a focus on preventing environmental losses, and the integration of local communities into environmental planning processes. An effective bioeconomic system for

agricultural development primarily involves the formation of a sustainable ecological infrastructure and the rational use of natural resources [5].

In this regard, it is relevant to expand the spectrum of practical solutions within the bioeconomic system, particularly through the efficient use of agricultural by-products. One of the promising directions for such an environmentally and economically viable transformation is the implementation of bioenergy technologies in agriculture.

Bioenergy is an important element on the path to energy independence for Ukraine. Utilizing biomass generated in agriculture for energy production significantly reduces energy costs and improves energy secu-

urity. Considering the potential of agricultural production waste as a source of bioenergy, this not only contributes to the reduction of greenhouse gas emissions but also brings additional income to producers. CO₂ emissions can be reduced by 8.2 million tons, which is an important step towards combating climate change.

The preservation of biodiversity is an important part of agrarian policy, which includes measures for the restoration of natural territories, improvement of the ecological condition of the land, and balanced land use. Ukraine must fulfill its commitments to biodiversity restoration, which involve the conservation of natural habitats and the implementation of innovative approaches to improve land use, including the introduction of digital technologies for monitoring and assessing the state of biodiversity, which will become the basis for effective natural resource management [12].

Post-war recovery of Ukraine's rural economy is impossible without the integration of innovative approaches into the bioeconomy, including organic production, circular bioeconomy, and biodiversity conservation. The State must support these areas to create conditions for the sustainable development of the agrarian sector and ensure food security. The implementation of these strategies will not only contribute to post-war recovery but also ensure the sustainable development of the economy in the long term, addressing the challenges of global sustainability and climate change.

CONCLUSIONS

Based on the conducted research, it can be concluded that bioeconomy is a key element for the post-war recovery of Ukraine's rural economy. It has been determined that one of the defining components of the bioeconomic transformation of the rural economy in the post-war period is the strategic management of environmental risks and the implementation of efficient waste management mechanisms. It has been clarified that the introduction of sustainable development principles, circularity, and efficient use of biological resources based on European strategies, such as the European Bioeconomy Strategy, should become a priority direction in the country's post-war recovery. It has been found that the development of bioeconomic technologies and local bioeconomies, the modernization of agricultural production, as well as the creation of waste disposal infrastructure will contribute to reducing ecological threats and restoring the natural environment, ensuring the long-term sustainability of agriculture after the war. It is worth noting that the implementation of bioeconomic approaches will not only restore physical production ca-

pacities but also create a basis for forming a sustainable, competitive rural economy, which will become an important component of Ukraine's socioeconomic development strategy.

The practical significance of the conducted research is that the conclusions and recommendations formulated by the author can be effectively applied to develop a strategy for the recovery of agriculture, which includes the integration of bioeconomic innovations and the implementation of circular economic models, thereby ensuring sustainable economic growth in the rural regions of Ukraine. Further scientific research in this area should be focused on a detailed study of the impact of bioeconomic technologies on the energy efficiency and environmental sustainability of agricultural production in the context of post-war rural economic recovery. ■

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