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Institutional support for the implementation of the circular economy in agribusiness

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Abstract. The aim of the study was to identify the key institutional support mechanisms necessary for the implementation of the circular economy in the agricultural sector of Ukraine, with a focus on adapting international best practices to local conditions. The study used content analysis of legislative acts, strategic documents and scientific sources, comparative analysis of institutional support models in the European Union, the United States, Australia and China, as well as statistical analysis of the current state of implementation of circular practices in Ukraine. The results of the

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study showed that successful implementation of the circular economy requires improvement of the regulatory framework, including the creation of tax incentives and government grant programmes for farmers, development of processing infrastructure, including regional agricultural waste processing centres, as well as intensification of educational initiatives to raise awareness of the benefits of circular approaches among farmers. The comparative analysis confirmed that the most effective support models are based on the synergy of government programmes, private investment and international assistance. The regional analysis revealed that, despite the negative impact of the war, the southern region of Ukraine retains significant potential for development due to its agricultural specialization. Innovations such as biogas plants and precision farming have been found to be able to meet up to 60% of farm energy needs and reduce water and fertilizer costs by up to 40%. However, the implementation of these approaches was constrained by limited funding and insufficient infrastructure. The study results highlighted the importance of a comprehensive approach to implementing circular economy principles, including legislative, financial and educational measures aimed at creating conditions for the economic, environmental and social sustainability of Ukraine's agricultural sector

Keywords: sustainable development; government regulation; agriculture; production cycle; environmental efficiency

INTRODUCTION

In today's world, rapid economic development is accompanied by an increase in resource consumption, which in turn leads to environmental problems and the depletion of natural resources. This problem is particularly acute in the agribusiness sector, where intensive use of land, water, and energy resources often upsets the ecosystem balance. In view of this, there is a need to introduce new approaches to managing production cycles and resources that ensure sustainable development. The circular economy is becoming increasingly important in global economic and environmental policy. Its concept is based on the integration of environmental, economic and social interests, contributing to sustainable development. In the context of agribusiness, which is one of the most important sectors of the economy in most countries, the implementation of circular approaches is crucial (Gavkalova *et al.*, 2024). This is due not only to the high dependence of agribusiness on natural resources, but also to its ability to generate a significant amount of waste that can be reused or recycled to create added value.

For Ukraine, as a country with a strong agricultural potential, the topic of circular economy is extremely important. The agricultural sector accounts for a significant portion of the country's gross domestic product, provides jobs in rural areas, and is an important export segment. At the same time, Ukrainian agribusiness is facing a number of challenges, such as soil degradation, dwindling water resources, and problems with waste storage and disposal (Shebanin *et al.*, 2024). All of this requires new approaches to managing production cycles and resources that could ensure the sustainability of the industry. Implementation of the circular economy in agribusiness requires an innovative approach that includes the development of new resource management mechanisms, integration of modern technologies and creation of favourable conditions for the development of circular practices. One of the key conditions for success is institutional support, which should ensure an effective combination of the economic interests of agribusiness and the requirements of sustainable development. The innovation of the circular economy lies in the transition from the traditional linear model of "production – consumption – disposal" to a cyclical model in which each product and resource is used for as long as possible (Szeląg-Sikora *et al.*, 2024). In the context of agribusiness, this means not only recycling and reusing waste, but also introducing precision farming technologies, producing organic fertilizers, using bioenergy resources and replacing synthetic materials with renewable ones.

Research on the circular economy is actively developing, and scientists from different countries are making a significant contribution to its theoretical justification and practical implementation. In this context, it is important to analyse approaches to implementing the circular economy in agribusiness through institutional support. Y.O. Akinwale (2023) notes that institutional support plays a key role in the implementation of circular approaches in Micro, Small & Medium Enterprises (MSMEs), which are the backbone of the agricultural sector in many countries. The author emphasizes the importance of financial assistance and the creation of knowledge-sharing platforms that stimulate the adoption of circular solutions in production chains. N. Arfaoui *et al.* (2024) investigate the impact of geographical proximity and organized partnerships on the effectiveness of circular economic practices. They argue that partnerships between farmers, government agencies, and private companies create synergies that facilitate the integration of circular approaches.

A.B.L. de Sousa Jabbour *et al.* (2023) focus on the use of Industry 4.0 technologies to optimize processes in food supply chains. They emphasize that digital tools, such as blockchain and the Internet of Things (IoT), allow for transparent waste management systems, which

is important for agribusiness. A. Berxolli *et al.* (2023) analyse the impact of martial law on the development of innovations in Ukrainian agriculture. The authors note that, despite the difficulties, agribusiness continues to integrate circular practices, such as the reuse of organic waste and the development of alternative energy. S. Viscardi *et al.* (2023) highlight the importance of integrating the circular economy into food waste management. The study demonstrates that the introduction of composting, recycling and secondary product creation systems significantly reduces resource losses in the food sector.

Despite significant progress in the implementation of the circular economy in agribusiness globally, in Ukraine this process faces numerous challenges that limit its effectiveness. The main problem is the absence of a coherent institutional framework that would stimulate the use of circular approaches in agriculture. The purpose of this study was to develop effective mechanisms of an institutional model for the implementation of circular economy principles in agribusiness. The study aims to create a framework for the introduction of innovative approaches to resource management that will allow Ukrainian agribusiness to integrate into global environmental and economic trends, while maintaining sustainability and productivity even in the face of limited resources.

MATERIALS AND METHODS

The study of institutional support for the implementation of the circular economy in agribusiness was based on the analysis of scientific sources, strategic reports of government agencies, and statistical data obtained from national and international resources. The main focus was on the practices of implementing the circular economy in the agricultural sector of Ukraine and in the countries of the European Union (EU), the USA, Australia and China, which have the most developed institutional support mechanisms. In particular, the provisions of Directive No. 2008/98/EC (2008), which regulates waste management in EU member states and promotes recycling, and the European Green Deal (2024) strategic initiative, which focuses on a climate-neutral economy and resource-efficient business models, were used.

Among the important sources was the national policy of India in the field of crop residue management, presented in the document "Crop residue management. Operational guidelines 2024" (Ministry of Agriculture & Farmers Welfare, 2024), which regulates the sustainable development of the agricultural sector. In addition, the innovative solutions of the international platform Indigo Agriculture, which specializes in developing technologies to optimize the use of resources in agriculture, were analysed. The international experience was also presented by the United States Department of Agriculture (USDA) (2023), which supports sustainable development in US agriculture, as well as the Work plan on "Zero-waste City" pilot programme in China (2024), which aims to recycle agricultural waste into fertilizers and biofuels, creating closed production cycles.

The reports of the Ministry of Agrarian Policy and Food of Ukraine (2024) became an important source of information on the implementation of the National Waste Management Strategy until 2030. In addition, information from the Ministry of Finance of Ukraine (2024) on state support programmes for the agricultural sector was analysed, as well as data from the Open Budget Portal, which provides access to information on the use of budget funds. The main part of the information support was provided by the AgroStats Platform (2024), which contains statistical information on the state of the Ukrainian agricultural sector, including production volumes, crop areas and the implementation of innovative practices. These sources provided a comprehensive study of the legislative, financial and infrastructural aspects of the circular economy, allowing us to take into account international experience and adapt it to Ukrainian conditions.

The main research methods used were content analysis, comparative analysis, and statistical data analysis:

1. Content analysis was used for a systematic review of scientific sources, legislative acts and strategic documents. This allowed us to identify key factors of institutional support, such as tax benefits, financial incentives and educational initiatives. The method provided a structured approach to studying various aspects of government policies and practices in the circular economy, allowing for the identification of the most effective approaches.

2. Comparative analysis was used to assess the institutional support models of the EU, the US, and Asia. This method allowed us to compare the economic efficiency, environmental impact, and adaptability of these models to Ukraine's conditions. Particular attention was paid to financing practices, agricultural waste recycling systems, and cooperative development, which helped to identify the best international practices.

3. Statistical data analysis was used to evaluate data on the implementation of the circular economy in agriculture, including financial indicators, volumes of agricultural waste processing and the level of implementation of innovative technologies. This method allowed us to identify trends, assess the effectiveness of government support, and identify key barriers to the transition to circular models.

In addition, the study used formula (1) to calculate the forecast indicator for the amount of state funding for 2025:

$$F_{2025} = F_{2024} + \Delta F_{average}, \quad (1)$$

where F_{2025} – projected funding for 2025, F_{2024} – amount of funding in 2024, $\Delta F_{average}$ – average increase in funding over previous years.

In turn, $\Delta F_{average}$ is calculated as follows (2):

$$\Delta F_{average} = \frac{\sum(\Delta F)}{n}, \quad (2)$$

where ΔF is the increment between adjacent years (F_n – F_{n-1}), n is the number of increments (one less than the number of years in the period).

Given the analysis, recommendations were developed to improve the institutional support for the implementation of the circular economy in Ukraine. The content analysis allowed us to identify key aspects that need to be improved, in particular in the areas of financing and infrastructure development. A comparative analysis of support models in different countries showed that the most effective are those that combine public initiatives with private investment. Statistical analysis has identified opportunities for the development of recycling infrastructure and barriers related to insufficient funding and limited access to modern technologies.

RESULTS

The circular economy in agriculture worldwide is based on the idea of maximizing the use of resources while minimizing waste, which allows for added value and sustainable development. In Europe, the implementation of the circular economy is guided by legislative initiatives and the European Green Deal programme, which defines the transition to resource-efficient management systems. The Netherlands, for example, demonstrates a successful model of using biogas plants for processing livestock waste, which not only reduces waste but also provides farmers with an additional source of energy (Bianchi *et al.*, 2022). In the United States, the circular economy is largely based on public-private initiatives. Companies such as Indigo Agriculture are developing technologies to optimize resource use, including precision agriculture and regenerative practices (Lucas & Löschke, 2024). Subsidies for innovation play a significant role in facilitating farmers' transition to circular models.

The Asian region, in particular China, is focusing on large-scale national programmes to integrate traditional farming methods with modern technologies. As part of the Zero-waste City programme, numerous farmers' cooperatives have been established to process livestock waste into fertilizers and biofuels, which can significantly reduce environmental costs (Work plan..., 2018; Feng & Lam, 2021). The effective implementation of the circular economy in agribusiness largely depends on institutional support that provides the necessary conditions for the development of innovative business models. In global practice, there is a variety of institutional mechanisms that allow for the promotion of circular approaches adapted to local circumstances. In the EU, institutional support for the implementation of the circular economy is based on the creation of a regulatory framework that obliges member states to adhere to sustainable principles in agriculture. The European Green Deal provides funding for projects aimed at reducing waste, restoring natural resources, and transitioning to environmentally friendly technologies. Specialized support programmes for small farmers play an important role, allowing them to integrate circular practices even on a small scale.

In the United States, preference is given to public-private partnerships, where the role of the state is to stimulate innovation through subsidies and grants, and business is the main driver of change. The USDA actively supports the development of environmentally sustainable practices by funding projects in the areas of waste recycling and organic farming. Institutional support includes the creation of technology parks, where farmers have access to the latest technology and advisory assistance. Asian countries, in particular China, are taking a different approach. Government support here is large-scale and focuses on stimulating agricultural cooperatives. Significant funds are being invested in the development of waste recycling infrastructure, which allows for the creation of closed production cycles. The Zero-waste City programme has received significant funding from the state, which has contributed to the conversion of 80% of livestock waste into organic fertilizers (Work plan..., 2018; Niang *et al.*, 2024).

The practical experience of implementing the circular economy in agribusiness around the world demonstrates how effectively organized institutional models contribute to economic, environmental and social sustainability. Unique cases have emerged in different countries that clearly illustrate the benefits of circular approaches. One of the most striking examples is the Netherlands, where farms are integrating biogas systems. Livestock waste, which traditionally posed environmental risks, is now used for biogas production (Portillo-Tarragona *et al.*, 2024). This allows not only to provide farmers with energy, but also to generate additional income through the sale of excess energy. The success of this model largely depends on the support of the government, which finances the installation of biogas plants and compensates part of the farmers' costs. In the United States, the experience of the Indigo Agriculture platform, which implements the principles of regenerative agriculture, is worthy of note. Using data analysis technologies, the company helps farmers optimize the use of resources, including water, fertilizers, and pesticides. This not only increases yields but also reduces the environmental footprint of agriculture. Indigo Agriculture operates a public-private partnership scheme that incentivizes farmers through financial and technical support.

In China, the Zero-waste City project has become a model of a government programme aimed at large-scale implementation of circular practices (Work plan..., 2018). As part of this initiative, dozens of

co-operatives have been established to process agricultural waste into fertilizers and biofuels. This approach has significantly reduced farmers' costs for purchasing chemical fertilizers, while reducing environmental pollution. A feature of the Chinese model is the full integration of government support with business efforts, which ensured effective project implementation even in remote regions. Denmark, as part of the EU, also demonstrates a successful case. The country's farms use organic waste to create a closed production cycle. For example, livestock waste is converted into organic fertilizer, which is used to grow grain crops (Sarfraz *et al.*, 2023; Shubalyi *et al.*, 2024). In turn, the grain serves as animal feed, completing the ecological cycle. Government programmes to support the circular economy promote the establishment of such systems through subsidies and training programmes.

Other interesting examples include South Africa, where AgriProtein uses organic waste to raise insects that are then processed into animal feed (Portillo-Tarragona *et al.*, 2024). This model has helped reduce organic waste while creating a new business segment. Thanks to technological innovation and partnership with the government, the project has gained international recognition. All these examples demonstrate that the success of the circular economy depends not only on innovative solutions but also on systemic institutional support. The integration of government initiatives, private business and international organizations allows for the creation of stable and effective circular concepts that can be applied to other countries, including Ukraine. Table 1 below shows a comparative analysis of the main circular economy models in the agricultural sector of three key regions: Europe, the US and Asia.

***Table 1**. Comparative analysis of circular economy models of the agricultural sector in Europe, the USA, and Asia*

Region	Basic principles	Legislative instruments	Examples
Europe	Resource efficiency, innovations in waste management, development of biogas technologies	European Green Deal, directives on waste recycling (Directive No. 2008/98/EC)	Netherlands: biogas farms, France: organic fertilizers from waste
USA	Public-private partnerships, focus on innovations (IoT, AI) to optimize resources	USDA Sustainable Agriculture Programme, subsidies for agribusinesses	Indigo Agriculture: precision farming, Californian Farms: minimizing water consumption
Asia	Large-scale integration of traditional approaches with modern technologies, creation of agro-cooperatives	National programmes such as Zero-waste City, support for cooperatives	China: 'Zero-waste City', India: recycling residues into fuel

***Source:** created by the authors based on the European Green Deal (2024), Directive No. 2008/98/EC (2008), USDA highlights progress in partnership with farmers to increase innovative domestic fertilizer production, expanding double cropping by investing in the American Agenda (2023), Leader in Sustainable Agriculture (2024), Work Plan for the Zero-Waste City Pilot Programme in China (2024), Ministry of Agriculture & Farmers Welfare (2024)*

Different approaches are used in each region, depending on local characteristics, economic conditions and the level of institutional support. The European model focuses on legislative initiatives and the development of resource efficiency. In the US, the emphasis is on innovation and public-private partnerships. The Asian approach focuses on large-scale government programmes and the integration of traditional practices with modern technologies. The table also illustrates specific examples of the implementation of these approaches, which can serve as a guide for other countries, including Ukraine. Ukraine is at the initial stage of implementing the circular economy, and the legislative framework plays a key role in this process. Today, national legislation partially integrates certain principles of the circular economy, but the lack of a comprehensive approach slows down the pace of adaptation to global environmental challenges.

One of the key regulatory acts is the Law of Ukraine No. 187/98-VR (1998), which regulates waste management and obliges business entities to take measures to recycle waste. Nevertheless, the legislation does not sufficiently stimulate the use of waste as a secondary resource, which is one of the main principles of the circular economy. The National Strategy for Waste Management in Ukraine until 2030 (2017) was approved, based on the principles of the European Waste Reduction Directive and envisaging the gradual introduction of a recycling system. However, its implementation in agribusiness remains fragmented. Another key document is the Law of Ukraine No. 1877-IV (2004), which provides partial reimbursement of costs for the introduction of modern technologies in this area. However, in the context of the circular economy, its provisions do not take into account the specifics of sustainable resource management. Successful examples include the harmonization of national legislation with European legislation, including the implementation of certain provisions of EU directives on waste management and bioenergy. For example, Ukrainian farmers have gained access to international financing programmes, such as the European Green Deal (2024), which promote the implementation of circular practices.

The main challenges of the legal framework include the lack of clear mechanisms to encourage agribusinesses to adopt circular models, insufficient

coordination between authorities, and weak integration of public and private initiatives. These constraints hinder the development of the circular economy in Ukraine, while creating opportunities for its improvement by adopting international experience. The circular economy in the agricultural sector of Ukraine is beginning to gain relevance in the context of growing environmental challenges and the need for efficient use of resources. However, the level of adoption of circular practices remains low due to a limited number of institutional mechanisms, insufficient funding, and low awareness of the benefits of this model among farmers. Individual farms and large agricultural holdings are showing initial success in applying circular approaches. For example, some enterprises are actively implementing biogas plants for processing livestock waste, which provide energy autonomy for farms. Others are using agricultural waste to produce organic fertilizers, which reduces the cost of purchasing chemicals. However, such practices are sporadic and largely dependent on international grants or financial support from foreign organizations. At the same time, there is a lack of local programmes in Ukraine targeted specifically at the agricultural sector, which significantly limits the ability of farmers to implement circular approaches.

An analysis of regional implementation of the circular economy shows significant differences between regions. In the southern regions, where large agricultural enterprises predominate, the use of innovative technologies is more possible due to access to resources and financing. At the same time, small farms in the central and western regions face financial barriers that hinder innovation. It should also be taken into account that the southern region of Ukraine, which covers Kherson, Mykolaiv, Zaporizhzhia and Odesa oblasts, has always played an important role in ensuring the country's food security due to its agricultural specialization. However, the full-scale war has significantly affected its functioning. The partial occupation of territories, the destruction of infrastructure and the constant threat of hostilities pose significant obstacles to the implementation of a circular economy that requires stability and investment. Nevertheless, even in such circumstances, there are still some initiatives in the region that demonstrate resilience and adaptation to new realities. Drip irrigation systems, which are key to the southern region due to its arid climate, remain critical even in the face of conflict. In the communities under Ukrainian control, farmers are trying to preserve and develop these systems as they save water, which has become even more scarce due to the destruction and damage to irrigation infrastructure, including the Kakhovka hydroelectric power station.

At the same time, precision agriculture, which involves monitoring soil conditions and moisture using IoT technologies, remains accessible only to large agricultural holdings. The war has made it harder for small farmers to access the necessary equipment and financing, which significantly narrows the range of farms that can implement these innovations. The war has created new challenges for agricultural waste management, in particular due to the damage to supply chains. Nevertheless, farmers in areas not occupied by the enemy continue to use agricultural residues to produce fuel briquettes and organic fertilizers. For example, in Mykolaiv region, agricultural cooperatives are working to restore processing facilities using available resources. However, such initiatives remain sporadic due to a lack of finance and risks associated with the hostilities (Dovgal *et al.*, 2024).

Prior to the war, biogas plants were actively implemented in the southern region, especially by large agricultural companies (Dovgal *et al.*, 2024). However, their operation is currently significantly limited due to disruptions in the supply of raw materials and the destruction of infrastructure. For example, some biogas complexes in Zaporizhzhia region have ceased operations due to their proximity to the frontline. At the same time, in relatively safe areas, such as the north of Odesa region, these systems remain viable and provide energy independence for farms. In the difficult conditions of war, the role of agricultural cooperatives is growing, as they are becoming centres of mutual assistance for farmers. In communities that remain under Ukrainian control, cooperatives support farmers with access to common resources, such as processing plants or irrigation equipment.

Despite all the challenges, the southern region has significant potential for post-war recovery and the development of a circular economy. Rebuilding irrigation infrastructure, introducing new technologies for efficient resource use, and expanding international assistance could form the basis for the region's sustainable development. Integration of international experience in agricultural waste processing and soil restoration will be of particular importance.The implementation of the circular economy in the agricultural sector of Ukraine faces a number of barriers that limit the possibility of an effective transition to a new model of management. These obstacles are both systemic and situational in nature, driven by current economic, infrastructure and military challenges. The main ones are listed in Table 2.

Ukrainian legislation is only partially adapted to the principles of the circular economy. The absence of clear regulations that would stimulate the recycling of agricultural waste and the introduction of innovations significantly hinders the development of the industry. For example, the absence of tax breaks or subsidies for the use of secondary resources reduces the economic motivation for farmers and agriholdings. In addition, the legal framework does not provide for mechanisms to monitor compliance with the principles of sustainable resource use. The low level of coordination between government agencies makes it difficult to implement

government support programmes, particularly in the agricultural sector. One of the key obstacles is limited access to finance. Due to the economic instability caused by the war, resources in the agricultural sector are mainly directed to basic needs, such as the sowing campaign and harvesting. Investment in long-term projects related to the circular economy remains minimal. The main obstacle to the implementation of the circular economy in the agricultural sector of Ukraine is limited funding from the state budget. The economic instability caused by the war has significantly reduced the state's ability to support innovative programmes, particularly in the areas of sustainable development and waste recycling.

***Table 2**. Main barriers to the implementation of the circular economy in Ukraine*

Barrier type	Description	Examples
Legal and regulatory	Lack of a clear regulatory framework, lack of incentives for recycling.	Lack of tax benefits, insufficient coordination between authorities.
Financial constraints	Limited access to financing, lack of credit programs for small farmers.	Small farms do not have the resources to install biogas plants.
Infrastructure constraints	Lack of infrastructure for waste processing, destruction of facilities due to war.	Lack of modern waste sorting and recycling centres.
Technological and educational barriers	Lack of modern technologies, low level of educational programs for farmers.	High cost of technology, insufficient access to innovation.
Social and cultural	Stereotypes about innovation, low willingness to change traditional approaches.	Distrust of new models, low awareness of the benefits of the Circular Economy.
Impact of war	Destruction of infrastructure, shortage of resources, focus on basic needs.	Interruption of logistics chains, destruction of production facilities.

***Source:** created by the authors*

The state budget, which is focused on critical needs such as defence, social protection and infrastructure rehabilitation, leaves few resources to finance long-term projects. With limited funding, the agricultural sector receives support mainly for basic needs, such as seeds, fuel, and the restoration of partially destroyed facilities, but not for the development of innovation or processing systems. It is worth considering the amount of state budget funds allocated for 2020-2024 (Fig. 1).

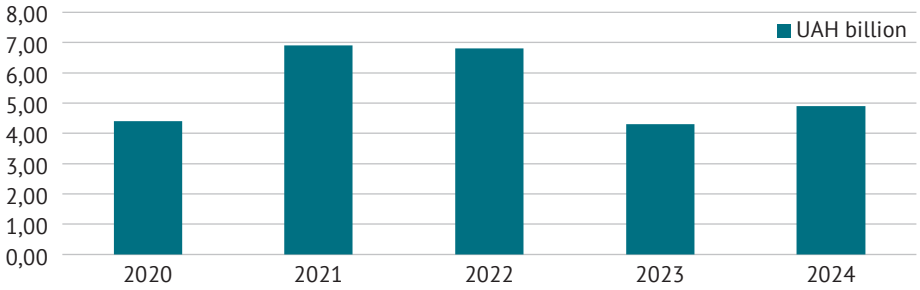

***Figure 1**. State financing of the agricultural sector of Ukraine (2020-2024)*
***Source:** created by the author based on data by Ministry of Finance of Ukraine (2024) and Ministry of Agrarian Policy and Food of Ukraine (2024)*

Analysing the data on the allocation of funds for the agricultural sector of Ukraine from the state budget for 2020-2024, we can note significant fluctuations in funding. The highest level of support was observed in 2021, when UAH 6.90 billion was allocated, indicating a significant focus on the development of the agricultural sector during this period. In 2022, funding remained at a high level (UAH 6.80 billion), which was likely due to the need to maintain the stability of agricultural production amid the deteriorating economic situation. However, in 2023, the amount of funding decreased significantly to UAH 4.30 billion, likely due to the reorientation of public resources to critical needs, including defence and social support, as a result of the war. In 2024, funding slightly increased to UAH 4.90 billion, indicating a gradual stabilization of the situation and attempts by the state to resume support for the agricultural sector.

In general, the trend shows a decrease in state funding for the agricultural sector since 2021, due to economic instability and the need to respond to the challenges posed by the war. At the same time, the growth in 2024 may indicate the state's efforts to promote the recovery of the agricultural sector even in the face of limited resources. For 2025, it is possible to make a forecast of the amount of state funding for the

agricultural sector based on the average level of funding for 2020-2024, which is UAH 5.725 billion. Given that in 2024, compared to 2023, there was an increase in funding from UAH 4.30 billion to UAH 4.90 billion, there is reason to expect a further gradual resumption of support for the agricultural sector. The average growth formula was used to calculate the forecast.

$$\Delta F_1 = 6.8 - 6.9 = \text{-UAH 0.1 billion}$$
$$\Delta F_2 = 4.3 - 6.8 = \text{-UAH 2.5 billion}$$
$$\Delta F_3 = 4.9 - 4.3 = \text{UAH 0.6 billion}$$
$$\Delta F_{average} = \frac{-0.1-2.5+0.}{3} = \text{-UAH 0.67 billion}$$
$$F_{2025} = 4.9 + (-0.67) = \text{UAH 4.23 billion}$$

Based on the calculations, the projected financing of the Ukrainian agricultural sector for 2025 is UAH 4.23 billion, which indicates a likely continuation of the trend of reducing the amount of state support. However, this forecast is relative, as it is based on average growth rates in recent years, while the actual economic situation in the country remains unstable and depends on a number of unpredictable factors, such as the duration of the war, the state of the economy, state budget priorities and international assistance. Despite the negative trend, the observed increase in funding in 2024 compared to 2023 may indicate a gradual renewal of the state's attention to supporting the agricultural sector. Further government actions, such as expanding subsidy programmes, stimulating innovation, and attracting international resources, could significantly change this outlook and ensure that funding stabilizes or even grows in the future.

Small farms often do not have access to loans or grants that could help cover the upfront costs of introducing new technologies, such as biogas plants or waste management systems. For many of them, this barrier is crucial. The development of a circular economy requires modern infrastructure for waste processing, logistics and storage of secondary materials. In most regions of Ukraine, such infrastructure is either absent or in poor condition. This is particularly evident in the southern and eastern regions, where the war has destroyed production facilities, including lifts, irrigation systems and processing plants. Even in peaceful regions, there is a lack of processing facilities that could be integrated into a circular economy. Outdated technologies and the lack of waste sorting centres further complicate the transition to the new model. Insufficient adoption of innovative technologies remains a significant obstacle. Farmers often do not have access to modern technologies due to their high cost or lack of skilled personnel to work with these technologies.

The educational aspect is also critical. Many farmers are not aware of the benefits of a circular economy, such as saving resources or creating additional sources of income through waste recycling. The lack of training programmes and advisory centres exacerbates this problem. The circular economy requires a change in mindset, both at the level of farmers and in society as a whole. Lack of trust in innovation, stereotypes about the high complexity of technology, and low willingness to change traditional approaches to farming create additional barriers. Military actions significantly complicate the implementation of the circular economy, especially in regions affected by occupation or hostilities. Destruction of infrastructure, lack of access to resources, and constant security threats force farmers to focus on the minimum necessary operations to ensure production. Given the statistical data, it is worth noting that the war has had a significant impact on the sown area in Ukraine (AgroStats Platform, 2024; Ministry of Agrarian Policy and Food of Ukraine, 2024). In 2018-2020, the sown area was stable at 46.0-46.5% of the country's total area, and in 2021 it increased to 47.4%. However, in 2022, this figure dropped to 38.8% (data for 2023-2024 are not available). In such circumstances, long-term projects, including the circular economy, are often postponed indefinitely. Effective implementation of the circular economy in the agricultural sector of Ukraine requires active participation of both the state and business. Taking into account the existing barriers, recommendations have been developed to overcome the main obstacles and stimulate the transition to circular economy models (Table 3).

***Table 3**. Recommendations for the development of a circular economy in the agricultural sector of Ukraine*

Category	Recommendations	Expected result
Public policy	Development of a national circular economy strategy, adaptation of European directives, creation of tax benefits.	Favourable legislative environment, stimulation of recycling.
Business initiatives	Investments in biogas plants, waste processing, and the introduction of precision agriculture.	Increasing energy independence, reducing costs.
International integration	Participation in European programs Green Deal, attracting international financing and technology.	Access to the latest technologies, project financing.
Technological solutions	Creating digital platforms for resource management, implementing IoT and AI.	Optimizing resource use, reducing environmental impact.
Regional cooperation	Formation of agroclusters for the joint use of processing facilities.	Reducing costs, increasing efficiency.
Educational programs	Organization of trainings for farmers, creation of demonstration centres.	Raising awareness, access to the latest technologies.

Table 3. Continued

Category	Recommendations	Expected result
Recovery after the war	Development of a roadmap for infrastructure restoration and attracting investors.	Rapid restoration of critical infrastructure facilities.
Social aspect	Creating jobs in rural areas, engaging communities in circular projects.	Increasing social cohesion, creating sustainable communities.

Source: *created by the authors*

The key for the state is to create a favourable legislative environment that takes into account the specifics of the circular economy. This involves the development of a national development strategy, with a focus on the agricultural sector. Amendments to existing legislation are needed to encourage the recycling of agricultural waste, such as the introduction of tax incentives for companies that use secondary resources and the integration of European directives into national policies. Particular attention should be paid to financial support. It is proposed to create grant programmes and soft loans for small farms that plan to implement innovative systems, such as biogas plants or precision farming technologies. It is also important to attract international assistance to rebuild the infrastructure destroyed by the war and to invest in the creation of regional agricultural waste processing centres that could provide farmers with access to modern technologies. The government should support educational programmes for farmers aimed at raising awareness of the benefits of a circular economy. These could include trainings, information platforms, or the creation of a network for sharing successful cases. The development of educational initiatives will help to create a new culture of resource management that will form the basis for long-term development.

For businesses, the priority is to optimize the use of resources and introduce innovations. One of the most promising areas is the use of harvest residues to produce fuel briquettes or organic fertilizers. This will minimize waste and create additional sources of income. At the same time, the use of precision farming technologies will help to use water, fertilizers, and pesticides more efficiently, which will not only reduce costs but also help to preserve natural resources. Investing in innovative technologies, such as biogas plants, can ensure energy independence for farms and significantly reduce their environmental footprint. In addition, businesses can play a key role in the development of local cooperatives that will help small farms integrate into the circular economy. This will contribute to the formation of sustainable agricultural communities that can effectively interact and solve common problems. The introduction of the circular economy in Ukraine's agricultural sector has the potential to significantly change the country's economic, environmental and social landscape. In terms of economic benefits, using crop residues such as straw or sunflower husks to produce biofuels or organic fertilizers can significantly reduce farmers' energy and chemical costs. For example, biogas plants can meet up to 60% of farm energy needs, which contributes to their energy independence. Precision farming technologies that optimize the use of water and fertilizers can reduce costs by 30-40%, while increasing yields and reducing environmental impact (Williams, 2022).

The environmental effect of implementing a circular economy is to reduce environmental pollution. Recycling organic waste into fertilizers and fuel reduces the amount of waste that goes to landfills and reduces greenhouse gas emissions. The conservation of natural resources, such as water, is made possible through the introduction of drip irrigation systems and soil monitoring technologies. In this way, the circular economy not only helps to reduce the negative impact of the agricultural sector on ecosystems, but also supports biodiversity and soil restoration. The social effect of the circular economy can be manifested in the creation of new jobs in rural areas, in particular in waste recycling, biofuel production, or organic fertilizers. Local recycling clusters and cooperatives can become centres of economic development for communities, contributing to the improvement of living standards in the regions. The integration of innovative practices will also help to strengthen social cohesion through the development of joint activities, the exchange of experience and the creation of opportunities for young people.

DISCUSSION

The results of the study confirm that the effectiveness of implementing the circular economy in agriculture largely depends on institutional support, which provides a regulatory framework, financial assistance and access to technology. Summarizing international experience allows us to better understand the variability of approaches to the integration of circular practices, which are shaped by regional characteristics. The EU experience presented in the research by M. Bianchi *et al.* (2022) emphasizes the importance of regulatory instruments, such as the European Green Deal, which provide a focus on natural resource recovery and waste reduction. The identified aspects of harmonization of state policy with international environmental initiatives are consistent with these findings. This study demonstrates that a similar approach could be adapted for Ukraine with a focus on supporting small farms, which are often left out of government programmes.

An analysis of the American model of the circular economy described by A.N. Lucas and S.K. Löschke (2024)

points to the key role of public-private partnerships and subsidies for innovation. The results of the study show that such a mechanism, focused on the active participation of business in financing and implementing technologies, can be effective for Ukrainian agribusiness. An important addition is the need to create technology parks and educational programmes that will allow small farms to join the innovation process. The Asian approach, in particular the results of research by K. Feng and C.-Y. Lam (2021), emphasizes the importance of government programmes and large-scale cooperative initiatives. In particular, the Zero-waste City programme in China demonstrates how centralized support can ensure large-scale waste recycling (Work plan..., 2018). The study also notes that the development of cooperatives and regional processing clusters could be an effective mechanism for Ukraine, given the limited resources of individual farmers.

The results of this study are consistent with the findings of A. Niang *et al.* (2024), who emphasize the importance of infrastructure for closed production cycles. Ukraine has the potential to adapt these practices in the context of post-war recovery, in particular by attracting international funding. Practical experience in implementing the circular economy in the agricultural sector confirms the importance of institutional support, innovative technologies, and business integration with government initiatives. Successful cases from the Netherlands, the US, China, Denmark, and South Africa demonstrate the diversity of approaches and the significant potential of circular practices to ensure economic, environmental, and social sustainability. The experience of the Netherlands is consistent with the findings of M. Sarfraz *et al.* (2023), who emphasize the importance of government subsidies and training programmes in creating closed production cycles. Dutch farmers effectively use biogas plants to process livestock waste, which reduces environmental risks and provides additional income. The results of the study confirm that a similar model can be adapted in Ukraine through incentives for small farmers and the creation of regional processing clusters.

The American approach, in particular the activities of Indigo Agriculture, emphasizes the role of public-private partnerships in the implementation of regenerative agriculture. This conclusion correlates with the research of A.N. Lucas and S.K. Löschke (2024), who note that companies that implement circular models receive both environmental and economic benefits. The study results also show that public-private partnerships can become one of the key tools for ensuring sustainable development, especially in conditions of limited public resources. China's Zero-waste City project identifies government support as the main driver of large-scale circular change (Work plan..., 2018). This approach is in line with the findings of J.N. Simon *et al.* (2022), who emphasize the importance of regional initiatives for the implementation of the circular economy. The Chinese model can serve as an example for Ukraine, where the development of cooperatives and public funding can integrate circular approaches into the agricultural sector. The original Danish approach, where farmers create closed production cycles using organic waste, is confirmed by L.A. Cisternas *et al.* (2022), who have studied circular strategies in various sectors. The importance of such cycles is to optimize resources and minimize waste, which is also promising for Ukraine, especially for the regions affected by the war.

South Africa's experience in using organic waste to grow insects opens up new horizons for innovative solutions in agriculture (Portillo-Tarragona *et al.*, 2024). This approach not only reduces waste, but also creates new market segments that can be useful for the Ukrainian agricultural sector. The study shows that the success of circular economy implementation depends not only on the availability of innovative solutions, but also on systemic institutional support, as outlined by C. de Laurentis *et al.* (2024). Integration of international experience allows for the adaptation of best practices to Ukrainian realities, in particular in the context of post-war recovery. Ukraine is at the initial stage of implementing the circular economy, and the results of the study show that one of the key challenges is to improve the legislative framework. The partial integration of circular economy principles into national regulations indicates the gradual adoption of European environmental standards. This is confirmed by the implementation of EU directives on waste management and bioenergy, which gives farmers access to international programmes such as the European Green Deal (Ciuła *et al.*, 2024).

The importance of legislative regulation is confirmed by the findings of A. Berxolli *et al.* (2023), who note that effective institutional support is a key factor in the development of innovation, even in the context of military challenges. At the same time, the study results show that Ukrainian legislation does not yet sufficiently stimulate the use of secondary resources, which creates barriers to the integration of circular approaches in agribusiness. Research by O. Dovgal *et al.* (2024) also confirms that the war has significantly increased the dependence of Ukraine's agricultural sector on international support. The practical successes of Ukrainian farms in implementing biogas plants and waste recycling indicate the potential for the development of local innovation models. This is in line with the findings of M.L. Tseng *et al.* (2024), who studied the implementation of circular approaches in the Vietnamese seafood industry and identified the importance of local initiatives in the context of global challenges. However, as the study shows, such practices remain sporadic, and their development is largely dependent on international grants and financial assistance.

The analysis of regional implementation of the circular economy in Ukraine shows significant differences

in the availability and implementation of innovative approaches between regions. The Southern region, despite its potential to ensure the country's food security, faces significant challenges due to the war. The partial occupation of territories, destruction of infrastructure and disruption of logistics chains complicate the possibility of sustainable development. Similar problems are reflected in the research of Waluyo and D.B. Kharisma (2023), who studied the impact of political and economic instability on the implementation of the circular economy in the agricultural sector in Indonesia. Drip irrigation systems, which are critical to the southern region due to the arid climate, continue to function even in the face of conflict. However, the war has exacerbated the problem of water shortages, which became acute after the destruction of the Kakhovka hydroelectric power station. This situation is similar to the experience described in the study by X.T. Qie *et al.* (2024), which emphasizes the importance of water management in rural China through the introduction of waste sorting systems and closed production cycles.

Biogas plants, which were previously actively implemented in the southern region, are currently limited in their operation due to the destruction of infrastructure and interruptions in the supply of raw materials. At the same time, the fact that they remain operational in relatively safe areas of Odesa region demonstrates the resilience of this technology. This is confirmed by the research of S.I.O. Herrera *et al.* (2023), who studied the impact of innovation on European farmers' decision-making to reduce emissions. The role of cooperatives as mutual aid centres in difficult war conditions is an important factor in supporting farmers. The study by A.S. Butt *et al.* (2024) highlights the importance of reverse logistics in shaping the circular economy and supporting sustainable development even in crisis conditions. The southern region of Ukraine demonstrates that cooperatives can serve as a platform for pooling farmers' resources, access to processing machinery, and maintaining farm productivity. The findings also point to the significant potential of the southern region for post-war recovery through the attraction of international assistance, the development of processing clusters and the introduction of innovative technologies. A similar approach is described in the work by S.I.O. Herrera *et al.* (2023), which emphasizes the role of cross-sectoral cooperation in the implementation of circular models.

The barriers to the implementation of the circular economy in the agricultural sector of Ukraine are multidimensional and deeply linked to economic, infrastructural and social challenges that have been exacerbated by the hostilities. The legal and regulatory framework is one of the key factors determining the possibility of transition to a new business model. However, according to the data obtained, its insufficient adaptation to the principles of the circular economy significantly slows down development. This is confirmed by the findings of F. Savini (2021), who notes that the lack of clear legal mechanisms and incentives for waste recycling creates significant barriers to the implementation of circular initiatives. Limited access to finance and lack of comprehensive government support is another significant barrier. As noted by O. Dovgal *et al.* (2024), military operations have significantly reduced the state budget's ability to finance long-term projects, including those in the field of sustainable development. These results confirm that Ukraine's agricultural sector mainly receives resources for basic needs, such as the sowing campaign, while innovative projects are not properly addressed. This is also in line with the research of M.C. Friant *et al.* (2023), who emphasize that innovative farming models require significant investment, especially in a context of limited financial resources.

The lack of modern infrastructure for waste processing and logistics is an additional barrier to the implementation of the circular economy. Outdated technologies and low levels of investment in the creation of recycling centres in most regions of Ukraine make it difficult to implement the principles of sustainable resource management (Nunes & Sytnychenko, 2024). This is reflected in studies by I. Auwalin *et al.* (2022), who point out that the availability of infrastructure is critical for a successful transition to a circular economy. The educational aspect and the level of awareness of farmers also remain important factors. Lack of knowledge about the benefits of the circular economy, such as resource savings or additional income generation through waste recycling, is one of the key reasons for the low level of innovation. According to I. Auwalin *et al.* (2022), public perception of innovation and trust in new technologies play a crucial role in the large-scale transition to circular practices. The war poses additional challenges for the implementation of the circular economy, in particular due to the destruction of infrastructure, loss of access to resources, and reduction of cultivated areas. According to AgroStats Platform (2024), the area under crops in Ukraine decreased from 47.4% in 2021 to 38.8% in 2022, which significantly affects the stability of the agricultural sector. Similar challenges are noted in the research of O. Dovgal *et al.* (2024), which points to the importance of adaptation strategies to ensure the sustainability of agriculture in times of crisis.

The development of recommendations for the implementation of the circular economy in the agricultural sector of Ukraine confirms the need for an integrated approach that combines the participation of the state, business and international partners. The proposed measures are in line with the research of D.C. de Vasconcelos *et al.* (2021), which emphasizes the importance of integrating legislative, financial and educational instruments in building sustainable fresh fruit supply chains in Brazil and the UK. Such approaches are universal and can be adapted to the Ukrainian agricultural sector. Amendments to national legislation, such

as the introduction of tax incentives for businesses that use secondary resources, are in line with the principles of promoting circular practices. This is confirmed by the findings of H. Moradnezhadi *et al.* (2023), who studied the behavioural aspects of farmers in the context of water recycling in Iranian agriculture. The study showed that financial support and educational programmes significantly increase farmers' readiness to integrate circular solutions. The development of educational initiatives such as trainings and information platforms aimed at raising awareness among farmers is also key. Lack of knowledge about the benefits of the circular economy remains a major barrier in many countries. This study noted that creating a network of successful case studies can significantly contribute to the promotion of circular models. This approach is supported by the research of D.C. de Vasconcelos *et al.* (2021), which highlights the role of educational initiatives in stimulating the transition to resource-efficient practices.

Optimizing the use of resources through the recycling of agricultural waste and the introduction of biogas plants is an important step towards reducing the ecological footprint of the agricultural sector. This is in line with the findings of H. Moradnezhadi *et al.* (2023), who note that such initiatives contribute to the creation of closed production cycles and reduce environmental impact. In addition, the development of local cooperatives and the integration of small farms into the circular economy contribute to the formation of sustainable agricultural communities. The proposed recommendations confirm that such measures can become the basis for effective adaptation of international experience to Ukrainian realities, taking into account the specifics of the Ukrainian agricultural sector. The introduction of a circular economy in the agricultural sector of Ukraine can provide significant economic, environmental and social benefits. The results of the study confirm that the use of crop residues for the production of biofuels or organic fertilizers not only reduces farmers' costs but also increases their energy independence. These findings are in line with J. Williams (2022), who emphasizes the importance of biogas plants in optimizing the energy needs of farms.

The environmental effect of the circular economy is to reduce environmental pollution and conserve natural resources (Golub *et al.*, 2017). For example, the processing of organic waste into fertilizer reduces the amount of waste that goes to landfills, while the introduction of drip irrigation and soil monitoring systems helps to save water. These results are in line with the study by L.E. Burgman (2022), who notes that the circular economy has significant potential to reduce the environmental impact of the agricultural sector. The social dimension of implementing a circular economy is also key. The creation of new jobs in waste processing, biofuels or organic fertilizers can be an important factor in the development of rural regions. This is confirmed by a study by A. Tittor (2021), who studied the role of agribusiness in Argentina's economic development, emphasizing the importance of local initiatives for community economic growth. Local processing clusters and cooperatives can contribute to economic development by leveraging shared resources and creating opportunities for young people. This approach is also in line with the findings of S. Viscardi *et al.* (2023), who point out the role of cooperatives in minimizing food waste and creating closed cycles in the supply chain.

CONCLUSIONS

The study found that institutional support is the foundation for the successful implementation of the circular economy. At the same time, it reveals specific challenges related to the constraints of Ukrainian agribusiness, such as lack of financing and infrastructure. Comparison with other countries allows us to identify best practices that can be adapted to Ukraine's conditions, opening up prospects for further research aimed at integrating global ones. The findings confirm the importance of combining government, business and international initiatives to implement the circular economy in Ukraine's agricultural sector. This opens prospects for further research aimed at localizing global approaches to sustainable development.

The results of the study show that effective implementation of the circular economy in Ukraine requires improvement of the legislative framework, intensification of institutional support and development of local initiatives. An analysis of successful practices from other countries and international studies allows us to identify prospects for adapting the best approaches to Ukrainian realities. This opens up opportunities for further research aimed at integrating the circular economy into sustainable development strategies for Ukrainian agribusiness. The regional analysis has shown that despite the significant challenges posed by the war, the southern region of Ukraine retains the potential for circular economy development. Integration of international experience, particularly in the areas of resource management, soil remediation and waste recycling, could form the basis for the sustainable development of this strategically important region.

The study found that effective implementation of the circular economy in the Ukrainian agricultural sector requires comprehensive measures, including improving the regulatory framework, developing infrastructure, raising awareness among farmers, and attracting international financial support. These approaches can serve as a basis for overcoming existing barriers and ensuring sustainable development of the agricultural sector in the face of current challenges. The developed recommendations are consistent with international research and demonstrate significant potential for overcoming barriers to the implementation of the circular economy in Ukraine. They are aimed at creating a favourable

environment for the development of innovative solutions in agriculture, which will ensure the economic, environmental and social sustainability of the agricultural sector. Thus, the results of the study confirm that the circular economy has the potential to transform Ukraine's agricultural sector, ensuring economic efficiency, environmental sustainability and social development. The integration of these approaches can ensure significant progress in the development of Ukrainian agriculture.

The study has certain limitations. One of the main ones is the timeframe of the analysis, which covers the last five years. This approach allows us to focus on current trends and most relevant practices, but may not take into account some long-term changes and previous research. In addition, data availability is another important factor that limits the completeness of the analysis. Some key indicators for recent years, such as statistics on crop area, waste volumes, or investments in recycling infrastructure, were not available due to the lack of open-source data. This leads to possible gaps in assessing long-term trends and the impact of the war on the agricultural sector.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Інституційна підтримка реалізації циркулярної економіки в агробізнесі

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Анотація. Метою дослідження було визначення ключових механізмів інституційної підтримки, необхідних для впровадження циркулярної економіки в аграрному секторі України, з акцентом на адаптацію найкращих міжнародних практик до локальних умов. У процесі дослідження було застосовано контент-аналіз законодавчих актів, стратегічних документів і наукових джерел, порівняльний аналіз інституційних моделей підтримки в країнах Європейського Союзу, США, Австралії та Китаї, а також статистичний аналіз сучасного стану впровадження циркулярних практик в Україні. Результати дослідження продемонстрували, що успішне впровадження циркулярної економіки вимагає вдосконалення нормативно-правової бази, включаючи створення податкових стимулів і державних грантових програм для фермерів, розвитку переробної інфраструктури, зокрема регіональних центрів переробки агровідходів, а також активізації освітніх ініціатив для підвищення обізнаності фермерів про переваги циркулярних підходів. Порівняльний аналіз підтвердив, що найефективніші моделі підтримки ґрунтуються на синергії державних програм, приватних інвестицій та міжнародної допомоги. Регіональний аналіз виявив, що, попри негативний вплив війни, південний регіон України зберігає значний потенціал для розвитку завдяки аграрній спеціалізації. Виявлено, що такі інновації, як біогазові установки та точне землеробство, можуть забезпечити до 60 % енергетичних потреб господарств і зменшити витрати на воду та добрива до 40 %. Однак реалізація цих підходів стримується обмеженим фінансуванням і недостатньою інфраструктурою. Результати дослідження підкреслили важливість застосування комплексного підходу до впровадження принципів циркулярної економіки, що включає законодавчі, фінансові та освітні заходи, спрямовані на створення умов для економічної, екологічної та соціальної стійкості агросектору України

Ключові слова: сталий розвиток; державне регулювання; сільське господарство; цикл виробництва; екологічна ефективність