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IMPLEMENTING A CIRCULAR ECONOMY STRATEGY IN UKRAINE'S AGRICULTURAL SECTOR

Keywords: agriculture, business management, circular economy, eco-innovations, strategy, Ukraine

ABSTRACT. This article develops a management strategy for Ukrainian agricultural enterprises based on circular economy principles. The study addresses the urgent need to restore resources, strengthen resilience, and align with the European Green Deal under martial law. It explores how agro-circular cycles can be integrated into enterprise management, which indicators best assess their efficiency, and what policy and organizational conditions enable large-scale adoption. The methodology combines analysis of Ukrainian and EU regulations and national statistics. Challenges include weak state support, war-related infrastructure damage, and low eco-innovation integration. Recommendations stress investments, biogas and biomass technologies, and institutional frameworks for sustainable recovery. The findings emphasize the importance of innovation as knowledge-driven eco-technologies that enhance efficiency and resilience. In this sense, the proposed actions contributes not only to sustainable growth but also to rural well-being, competitiveness, and long-term national security. These efforts will promote green economy principles, improve the well-being of rural populations, and boost social responsibility for energy recovery. Additionally, the state can play a crucial role in promoting green investments, fostering competitiveness among local green product producers, and encouraging a shift toward sustainable practices within the rural population.

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INTRODUCTION

The need for a long-term strategy in agricultural enterprise management arises from the goal of improving rural well-being and driving economic growth through innovation, given the sector's importance to the national economy. Globalization is intensifying, bringing exogenous factors that affect agricultural enterprises, particularly the development of a new type of agricultural production based on intellectualization and innovation. The statement that agricultural production is developing based on the "intellectualization of innovation" requires clarification. Innovation in agriculture is always linked to knowledge creation, but its forms are diverse and context-dependent. For example, Morales, Batlles-delaFuente, Cortés-García and Belmonte-Ureña (2021) and Rodino, Pop, Sterie, Giuca and Dumitru (2023) highlight that sustainable innovation in agricultural systems depends on the systemic integration of knowledge, technology, and socio-economic factors rather than on intellectualization alone. Therefore, in this paper, the notion of innovation refers to knowledge-driven eco-technologies that strengthen resource efficiency and resilience in the Ukrainian context.

In Ukraine, the implementation of the innovative circular economy in agricultural enterprises is at an early stage, hindered by war and economic instability, which have affected resource efficiency and environmental preservation (Zlotnik, Tkachuk, 2023). However, a well-founded management strategy is emerging, establishing national priorities for sustainable development in agriculture under unpredictable and risky conditions. Introducing the innovative circular economy into agricultural management strategies promotes synergy within the green economy, focusing on the circulation and rational use of resources to ensure sustainable economic growth (Khodakivska, Martynuik, Lupenko, 2023).

The core idea of the circular economy is the repeated return of resources for use in subsequent production cycles, promoting the preservation and more rational use of natural, production, financial, and personnel resources (Shvets, 2022). During martial law and state instability, the management strategy for agricultural enterprises should focus on restoring depleted natural resources, improving environmental efficiency, preventing overproduction, and responding to global challenges. This requires flexible solutions, reorienting enterprises towards cooperation with stakeholders and addressing environmental needs (Korhonen, 2021; Zlotnik, 2023).

Enterprise management should be aligned with the United Nations Sustainable Development Goals 2030, with a focus on sustainable development and the integration of circular innovations into the recovery processes of enterprises, alongside the restoration of their natural environment and the mapping of ecological and economic systems at the national level (Horbal, Lomaga, 2022). Research by Ansoff, H., Kipley, Lewis, Helm-Stevens and Ansoff, R. (2019), Sarkis and Zhu (2017), Xia and Ruan (2020), Zvarysh (2019), and Tymoshenko and Dronova (2018) demonstrates a transition from traditional industrial

models to innovative approaches, stressing sustainable development and the generation of unique value through material and intangible flows within the waste value chain.

Despite the increasing academic attention to circular economy in agriculture, important research gaps remain. For example, Morales et al. (2021) highlighted the trade-offs and synergies between sustainability and circularity, while Rodino et al. (2023) developed evaluation frameworks for circular agriculture. These studies are largely conceptual or generalized at the international level. There remains a lack of detailed analysis of how such principles can be adapted to the unique conditions of Ukraine, especially under war-related disruptions. This study therefore addresses the gap by contextualizing circular economy strategies within Ukraine's agricultural sector, where both environmental restoration and economic resilience are critical. The study examines Ukraine's agricultural sector and its transition to a circular economy from economic, environmental, and institutional perspectives. It develops a scientific approach to managing agricultural enterprises by applying universal methods and tools that ensure operational efficiency and sustainable enterprise structures through agricultural cycles and resource reuse in production.

MATERIAL AND METHODS

The methodological framework of this study is based on combining statistical analysis, policy document review, and theoretical elaboration of circular economy concepts in agriculture. The empirical basis includes statistical data from the State Statistics Service of Ukraine (SSSU, 2023), the National Waste Management Strategy until 2030 (DLF Attorneys-at-Law, 2021), and sectoral reports (Prokopenko, 2023). This dataset covers the period 2016-2023, providing insight into agricultural waste generation, processing, and investment flows. A mixed-methods approach was applied. Quantitative analysis focused on waste volumes, processing rates, and investment levels in circular practices. Qualitative analysis included content examination of strategic documents and academic literature on circular economy principles in agriculture. This dual perspective ensures both empirical grounding and theoretical interpretation of the agro-circular cycle.

In conceptual terms, the study recognizes that agriculture is inherently circular, particularly in nature-based systems such as organic and biodynamic farming. Biodynamic agriculture, for example, treats the farm as an organism where energy and matter circulate continuously within the system (Rigolot, Quantin, 2022). This is consistent with the cascading principle of circularity, where the by-products of one process serve as inputs for another, maximizing resource efficiency across the entire cycle. Incorporating these perspectives allows for a deeper understanding of how circular economy principles are not externally imposed on agriculture, but rather build upon and formalize practices already embedded in sustainable farming systems.

From a management standpoint, circular solutions in agriculture are implemented through two complementary approaches: the resource-oriented, which reorganizes flows of resources within the agro-circular cycle, and the economic-innovative, which treats circularity as a paradigm for reducing pollution and waste while fostering growth (Zvarych, 2019; Mealy, Teytelboym, 2020; Zlotnik, Tkachuk, 2023). These approaches are central to Ukraine's agricultural restructuring and resonate with the EU circular economy framework. They emphasize stakeholder interaction across consumers, suppliers, and authorities, enhancing competitiveness, environmental efficiency, and social responsibility (Khodakivska et al., 2023; Usata, 2023).

Closed agro-circular cycles aim to preserve and increase the value of natural, biological, and food resources by transforming agricultural waste into secondary raw materials, ensuring ecological and economic land management (Trusova et al., 2021a). EU member state experience highlights that land resources have limited exploitation cycles, with their fertility directly dependent on the responsibility of enterprises for the bioenvironment (Lupenko, Khodakivska, Nechyporenko, Shpykuliak, 2022; Trusova, Svynous, Prus, Havryk, Ivanovskiy, 2022; Shevchenko et al., 2022). The reuse of agricultural waste not only reduces raw material costs but also shifts ecological and economic criteria from quantitative to qualitative, aligning with the principles of circularity (Horbal, Plish, 2021).

For the purposes of this research, "cyclical mechanisms" are defined as both ecological cycles (such as soil nutrient and water cycles) and socio-economic cascades of resource use across production chains (Abuselidze et al., 2023). This broader definition ensures that the agro-circular model is not confined to environmental dimensions but also integrates economic, technological, and institutional aspects of resource management. To assess the effectiveness of implementing agro-circular strategies, we draw on existing evaluation frameworks for circular agriculture (Rodino et al., 2023), systemic analyses of synergies with sustainability goals (Smith, 2025), and indicators of resource reuse and sustainable land management developed in Ukrainian and EU practice (Trusova, Kalchenko, Pochernina, Kravets, Hurbyk, 2021b; Lupenko et al., 2022). These frameworks inform the interpretation of Ukraine's agricultural transition and guide the identification of policy and investment priorities for the post-war recovery period.

RESULTS

Agriculture is the primary sector of Ukraine's economy and a cornerstone for national food security. However, traditional agricultural practices, widespread throughout history, have caused significant environmental harm. These practices have contributed to the degradation of soils, pollution of water and air resources, reduced biodiversity, and inefficient use of natural resources. A critical issue in agriculture and related food industries

is the increasing volume of industrial and food waste, which continues to grow each year despite global food security concerns.

Globally, agriculture and food production account for over 70% of total water withdrawals, and approximately 80% of deforestation is linked to agricultural land use. To address these challenges, Ukraine has adopted strategic initiatives, including the Resolution "On the Establishment of the Coordination Council for the Implementation of the National Waste Management Strategy in Ukraine until 2030" (VRU, 2018) and the National Waste Management Strategy until 2030, to promote sustainable agricultural waste management practices.

Before the escalation of the military conflict, Ukraine had been witnessing a positive trend in reducing agricultural waste, which accounted for about 2.2% of the total waste generated by economic activities in 2019 (Figure 1). This reflects the potential for further progress in waste reduction and the integration of circular economy principles within Ukraine's agricultural sector.

Ukraine's agricultural sector, crucial for national food security, faces challenges from traditional practices that harm the environment, degrade soils, and pollute water and air. The volume of agricultural and food industry waste continues to rise, contributing to the global food security problem. To address this, Ukraine has adopted strategies like the

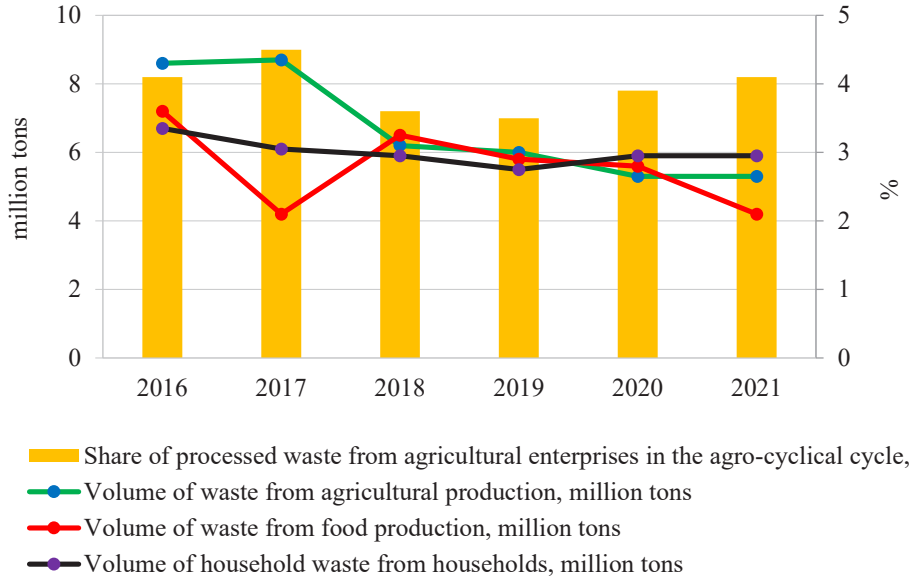

Figure 1. Volume of production waste and the share of its processing in the agro-circular cycle of agricultural enterprises in Ukraine for 2016-2021

Source: built based on (Prokopenko, 2023; SSSU, 2023)

National Waste Management Strategy and established a coordination council to implement these measures.

Before the war, Ukraine saw a positive trend in reducing agricultural waste, which made up about 2.2% of total waste generation. The primary waste materials are pulp (23.1%), poultry litter (11.6%), and sunflower husks (11.1%). These byproducts are repurposed for use as fertilizers, biogas, animal feed, or even biofuels. However, only 1.6% of waste is effectively recycled (Zlotnik, 2023). Adopting a circular economy strategy could significantly increase resource efficiency, boost land use sustainability, and drive economic growth. By 2025, this could add 2,347.42 million EUR in value. With annual waste generation before the war around 11 million tons, transitioning to a closed-loop agro-circular cycle is critical (DLF Attorneys-at-Law, 2021; SSSU, 2023; Smith, 2025). However, waste management is mostly limited to disposal, incineration, or storage, due to inadequate sorting facilities.

The key to success is restructuring agricultural production and logistics, introducing innovative technologies for waste processing, improving energy efficiency, and transitioning to a circular agro-food model. The main obstacles include a lack of state funding and insufficient infrastructure for eco-innovation. The effectiveness of this strategy will depend on reducing waste disposal costs and attracting capital investment (Figure 2).

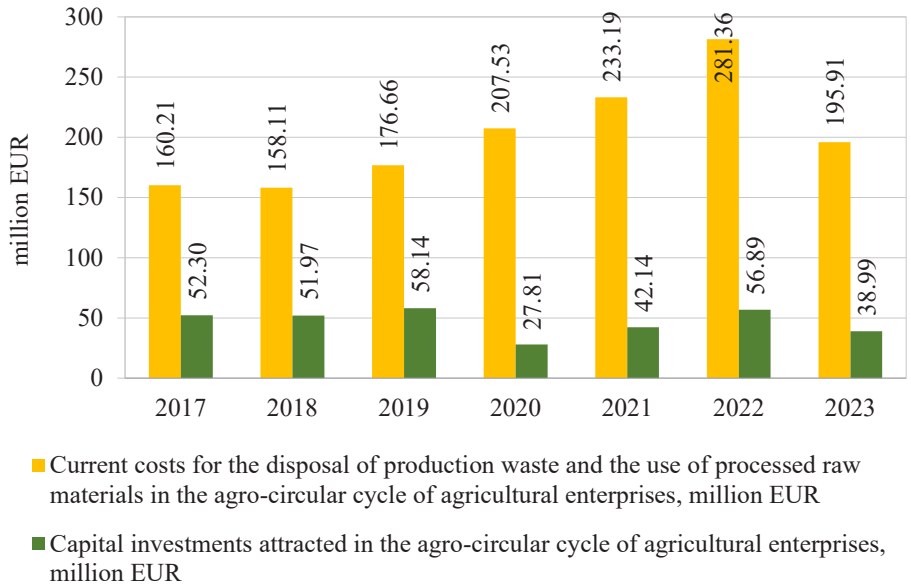

Figure 2. Current expenses and capital investments for the disposal of production waste and the use of processed raw materials by agricultural enterprises in Ukraine for 2017-2023

Source: built based on (Prokopenko, 2023; SSSU, 2023)

In 2023, there was a significant gap between the costs and capital investments required for waste disposal and the use of processed raw materials in the circular agro-food cycle of agricultural enterprises. The investment need amounted to 195.91 million EUR, showing a 30.4% decrease compared to 2022 and a 16% decrease from 2021. The average annual investment for developing a circular economy in Ukraine's agriculture is about 3% of the country's GDP.

The full-scale invasion of Russian troops has severely complicated the implementation of circular economy strategies. The ongoing conflict has led to substantial environmental threats, including groundwater contamination, increased waste, and mass burials of casualties. Military waste remains in agricultural fields, rural areas, and water sources (Zlotnik, Melnyk, 2020). Additionally, large quantities of military equipment (325,000 tons) have been left in areas affected by fighting, and many warehouses for plant protection products were destroyed, polluting water, soil, and air (Dergachova, Smerichevskyi, Kniazieva, Smerichevska, 2020). The Ministry of Environment and Natural Resources estimates the damage to natural capital and the environment at approximately 47 billion EUR.

The contamination of agricultural lands from military operations has severely affected natural capital. The majority of the waste (55%) comes from the destruction or partial damage to agricultural lands, particularly in territories previously under occupation and those still suffering from hostilities. The Ministry of Environment of Ukraine has developed a procedure for managing waste in rural areas and agricultural enterprises affected by the war (DLF Attorneys-at-Law, 2021; USM, 2023). This process emphasizes the role of local governments and agricultural enterprise leaders, but work can only begin if there is no risk of the collapse of structures or parts of structures. If no such threat exists, authorized bodies are tasked with organizing inspections, identifying demolition waste, determining storage sites, approving dismantling lists, preparing documentation, and coordinating primary dismantling. These actions are crucial to ensuring safety for emergency and rescue operations.

Temporary storage areas for demolition waste must be carefully located, with specific distances from critical locations: 2 km from water sources, 0.5 km from residential buildings and social infrastructure, 0.2 km from agricultural land, public roads, and railways, and 0.05 km from forests (VRU, 2018). The area should also include zones for sorting, recycling, storing secondary raw materials, and setting up necessary installations for waste management (USM, 2023). Figure 3 illustrates the comparison of agricultural waste management levels between the EU and Ukraine in 2023.

Ukraine has seen positive trends in agricultural waste management, with increased processing through composting, fermentation, and sustainable soil practices. This shift towards ecological and safe exploitation of natural resources has expanded the closed-type economic model, integrating all production and logistics chains within the agro-circular cycle. To implement this model, Ukraine needs substantial institutional, financial, and

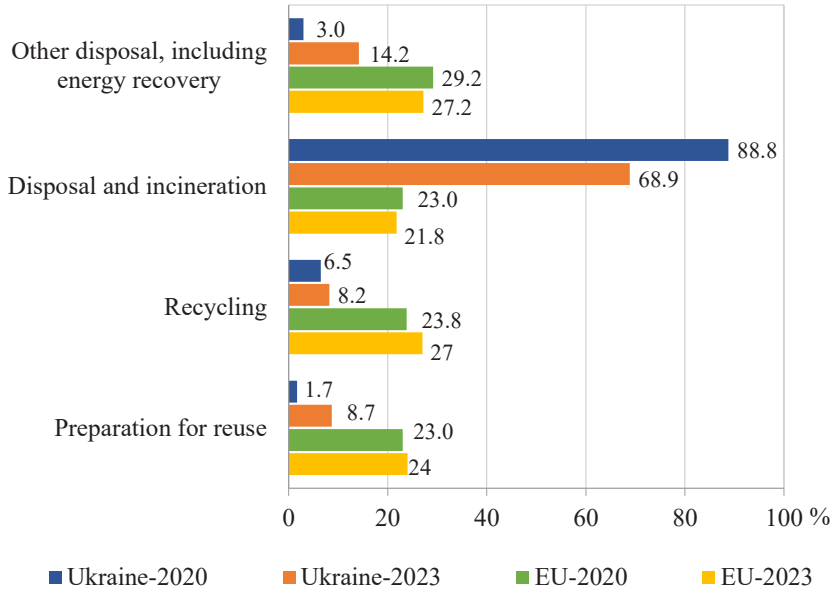

Figure 3. Agricultural waste management in Ukraine and the EU in 2023
Source: drawing based on (EIB, 2024)

informational support. European projects, like Biomodel Regions, offer a successful example, supporting the transition to circular models in agriculture across multiple EU countries with a 2.5 million EUR budget (EIB, 2024).

Challenges remain, such as limited resource and energy efficiency at the business level, lack of cooperation across production chains, and economic obstacles that hinder the full adoption of circular practices. Overcoming these barriers is essential for the successful implementation of a circular economy in Ukraine's agriculture.

Agricultural enterprises in Ukraine, with their traditionally "linear" business models, face difficulties in adopting circular practices due to macro-level restrictions, such as limited financing for circular innovation projects. Despite this, the linear economy in Ukraine continues to benefit from scaling agricultural circular cycles focused on optimizing production and consumption systems. Research and development, funded by the European Investment Bank (EIB), still predominantly supports linear agro-food cycles (EIB, 2024).

The EIB has outlined three key principles for integrating circular economy practices into agricultural management: 1) the need to limit resource use as the demand for raw materials increases, 2) continuous innovation in agro-food production technologies, and 3) the development of circular models that transform material resources into more efficient and environmentally safe production systems.

In Ukraine, agricultural enterprises are increasingly adopting "green" energy production as part of agro-circular cycles, recycling waste from agricultural and food production. Leading companies like Kernel, Nibulon, and Ukrprominvest-Agro utilize waste materials such as beet sugar industry by-products, chicken manure, and corn silage for bioenergy production. However, producing bioenergy resources like biomethane faces economic challenges, particularly regarding price competitiveness against traditional energy sources (Khodakivska, 2023).

Despite these hurdles, the bioenergy market holds considerable growth potential. For instance, EU countries are projected to need 35 billion m3 of biomethane by 2030. Ukraine's biomethane production potential is estimated at 21.8 billion m3, which could meet the demand from European companies on favorable economic terms (Kozachenko, 2024). Ukrainian agricultural enterprises, working with research institutes, are focusing on waste management, resource exchange, conservation of water and land, biodiversity preservation, and the integration of digital technologies to enhance the effectiveness of agro-circular cycles (Usata, 2023).

The closed-type agro-circular cycle model in agricultural enterprises emphasizes ecological and economic protection by preventing the overuse of natural resources and fostering sustainable practices. Key motives for its adoption include the rational use of primary materials, maximizing by-product processing, prioritizing biomass for energy and food production, and promoting entropy to enhance energy security through renewable resources (Usata, 2023). This model is multifunctional, aiming to minimize waste and optimize resource use, benefiting both agricultural enterprises and consumers.

The management strategy of agricultural enterprises in the closed-cycle model focuses on integrating alternative production methods, food sources, and value chains, combining economic and environmental benefits. A critical element for success is the reuse of renewable material resources, which help minimize waste and create new value chains. These resources play a vital role in implementing circular economy principles in agriculture.

Globally, the strategy for renewable material resources involves producing biomass as an energy source from agricultural and livestock waste. In the EU, biogas, biodiesel, and bioethanol are key bioenergy components, showing stable growth in recent years. While these energy carriers are primarily sourced from imported vegetable oils and oil crops, including from Ukraine, biomass helps reduce emissions, increase energy independence, and expand energy availability. EU countries currently produce about 950 tons of biomass, which meets 65% of their oil consumption (Otero et al., 2023).

Scaling up the management of reversible material resources allows agricultural enterprises to incorporate alternative energy sources through bioprocessing plants, which maximize added value across three key areas: the bioenvironment, economy, and agriculture. By 2050, three scenarios for biomass use are proposed. The first scenario

involves low biomass use, where about 25% of degraded agricultural land is used for production. The second scenario envisions increased biomass production through ecological farming practices on 50% of land affected by reduced fertility. The third scenario aims for energy security through alternative energy sources, focusing on eco-innovative technologies in sustainable agriculture and full waste utilization.

An example of effective circular material resource management is the potato production model in Lower Saxony, Germany. This model involves four large companies, including international agro-processors, food packaging firms, and a chip production company, as well as small farmers and various trade organizations. These participants, supported by financial, organizational, and technical consultants, implement sustainable farming practices, soil management, and energy-efficient production methods.

The main principle of managing circulating material resources in agricultural enterprises is environmentally friendly waste processing, with raw materials and resources reused within the production and logistics chain. By-products are utilized for biofuel production, organic fertilizers, and animal feed. This closed-type agro-cycle model reduces waste disposal costs, which account for more than 50% of raw materials used. The client base for this model includes supermarkets, restaurants, educational institutions, hospitals, and branded stores.

A key aspect of managing material return flows is the restoration of natural capital, such as agricultural lands and pastures, through new land relation scenarios between agricultural enterprises and local governments (Trusova et al., 2022; Zlotnik, 2023). Agricultural lands play a vital role in protecting the bioenvironment by ensuring the sustainable operation of product production models and maintaining soil fertility. Human resources also contribute through social and corporate responsibility, enhancing the bioenvironment and modifying the production landscape with bioenergy capacities. This creates a balance of labor intensity, productivity, energy intensity, and resource use per hectare of agricultural land (Trusova et al., 2022).

An objective assessment of the results from implementing the agro-circular cycle management strategy in agricultural enterprises across Ukraine identified regions with varying levels of effectiveness in optimizing waste use, resource management, economic benefits, and minimizing environmental impact. The regions with the highest effectiveness were Ternopil (92.7%), Kyiv (92.8%), Poltava (93.5%), Sumy (88.2%), Volyn (85.2%), Vinnytsia (85.7%), Cherkasy (85.5%), Dnipropetrovsk (88.4%), Zakarpattia (82.8%), Khmelnytskyi (81.7%), and Lviv (81.1%). In contrast, Kherson (29.4%) and Zaporizhia (26.4%) had low levels of implementation, mainly due to the significant destruction of infrastructure in rural areas and contamination of agricultural lands from military operations (SSSU, 2023; Smith, 2025; USM, 2023).

The UN Committee on World Food Security emphasizes that sustainable land use is largely dependent on coordinated efforts among agricultural stakeholders in planning and organizing agricultural land protection measures. This is a core aspect of the circular economy (Trusova et al., 2022), aiming to reduce anthropogenic pressure on the bioenvironment by preserving natural capital and protecting biodiversity (Lupenko et al., 2022).

Ukraine's total financial needs for agricultural reconstruction and restoration exceed 349 billion EUR, with international donors planning to allocate 750 billion EUR by 2032, of which 20 billion EUR is earmarked for restoring the bioenvironment in agriculture. However, this restoration doesn't mean returning to linear agricultural management strategies. Instead, it involves deeply integrating Ukraine into the European ecological and economic framework, aligning with the European Green Deal. This transition will allow Ukraine to establish new circular economy institutions based on innovation in the post-war recovery period.

CONCLUSIONS

Implementing a circular economy strategy in Ukraine's agricultural sector can drive technological advancements and support sustainable production, fostering economic growth. Transitioning to circular practices will ensure that all products are either used as final products or recycled as raw materials, addressing natural resource scarcity and reducing reliance on imports, especially in the context of closed borders. Key strategies include developing biogas plants for organic waste, repurposing agricultural byproducts for biofuels or fertilizers, and utilizing renewable energy sources like wind and solar power.

Adopting an agro-circular cycle will establish an integrated ecological and economic system involving all stakeholders, such as agricultural enterprises, food industry companies, and waste processing services. This system will help protect resources, minimize environmental impact, reduce CO_2 emissions, and support rural development.

Circular models offer substantial potential for enhancing the sustainability and efficiency of agricultural enterprises, provided they are supported by adapting international practices, improving rural infrastructure, and creating favorable conditions for eco-innovation. These efforts will promote green economy principles, improve the well-being of rural populations, and boost social responsibility for energy recovery. Additionally, the state can play a crucial role in promoting green investments, fostering competitiveness among local green product producers, and encouraging a shift toward sustainable practices within the rural population.

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WDRAŻANIE STRATEGII GOSPODARKI O OBIEGU ZAMKNIĘTYM W SEKTORZE ROLNYM UKRAINY

Słowa kluczowe: rolnictwo, zarządzanie przedsiębiorstwem, gospodarka o obiegu zamkniętym, ekoinnowacje, strategia, Ukraina

ABSTRAKT. W artykule przedstawiono strategię zarządzania dla ukraińskich przedsiębiorstw rolnych, opartą na zasadach gospodarki o obiegu zamkniętym. Badania dotyczyły pilnej potrzeby przywrócenia zasobów, wzmocnienia odporności i dostosowania się do Europejskiego Zielonego Ładu w warunkach stanu wojennego. Analizowano, w jaki sposób cykle rolnicze o obiegu zamkniętym można włączyć do zarządzania przedsiębiorstwem, jakie wskaźniki najlepiej oceniają ich efektywność oraz jakie warunki polityczne i organizacyjne umożliwiają ich wdrożenie na dużą skalę. W badaniach zastosowano analizę ukraińskich i unijnych przepisów oraz wykorzystano statystyki krajowe. Stwierdzono, że największymi wyzwaniami są: słabe wsparcie ze strony państwa, zniszczenia infrastruktury związane z wojną i niska integracja ekoinnowacji. W zaleceniach duży nacisk kładzie się na inwestycje, technologie biogazu i biomasy oraz ramy instytucjonalne dla zrównoważonej odbudowy. Podkreśla się także znaczenie innowacji opartych na wiedzy ekotechnologii, które zwiększają wydajność i odporność gospodarki. W tym sensie proponowane działania przyczyniają się nie tylko do zrównoważonego wzrostu, ale także do dobrobytu obszarów wiejskich, konkurencyjności i długoterminowego bezpieczeństwa narodowego. Działania te mogą promować zasady zielonej gospodarki, poprawiać dobrobyt ludności wiejskiej i zwiększać społeczną odpowiedzialność za odzyskiwanie energii. Ponadto państwo może odegrać kluczową rolę w promowaniu zielonych inwestycji, wzmacnianiu konkurencyjności lokalnych producentów ekologicznych produktów i zachęcaniu ludności wiejskiej do przechodzenia na zrównoważone praktyki.

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