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Organisation of the Cyclic Production in the Agricultural Sector of the Economy of Ukraine

Abstract

The *purpose* of this article is to identify and summarise the key issues and promising approaches to transitioning to a circular production model in Ukraine's agricultural sector in the context of the new economic environment. Theoretical research methods were employed to determine the main challenges associated with transitioning to a circular economy in agriculture and to outline ways of overcoming them. *Methodology*. The employment of quantitative methodologies enabled the demonstration of the characteristic features and anticipated socio-economic consequences of the operation of a circular economy, as well as the significance of the implementation of the paradigm of circular production, which is predicated on the concept of establishing self-sufficient cycles in which waste generated in one operation becomes a valuable resource for another. Empirical analysis has demonstrated that long-term values created within a closed production cycle in the agricultural sector form four types of added value: economic, environmental, consumer and informational. *Findings*. The analysis provides a foundation for the potential organisation of circular production in the agricultural sector, with a particular focus on biogas production, the utilisation of precision agriculture technologies, the establishment of composting stations, and the utilisation of waste as an alternative fuel. *Practical implications*. The introduction of circular production has been demonstrated to contribute to both ecosystem restoration and the economic growth of agricultural enterprises. The post-war state agro-ecological development strategy is substantiated, the full achievement of which is only possible in the presence of strong formal institutions for conducting business and the modernisation of the agribusiness on the principles of a circular economy. *Value/Originality*. The article under scrutiny here sets out to demonstrate the considerable efficiency potential of the transition to a circular economy in the agricultural sector of Ukraine. This transition is posited as an innovative model that would enable the creation of closed production cycles and effective waste management. Furthermore, it is argued that this would contribute to ecosystem restoration.

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circular economy, circular (cyclic) production, agricultural sector, resource efficiency, agri-food system, sustainable agriculture, green transformation, Ukraine

JEL: E20, F20, H57, L51, M11, Q20, R52

1 Introduction

The necessity of organising circular production in Ukraine's agricultural sector is determined by the need to increase resource efficiency and resilience of agri-food production in the context of the new economic environment. This environment is characterised by higher volatility of input prices and supply, tighter financial constraints and growing environmental and market requirements for sustainable production. In agriculture, circularity is directly linked to reducing losses of nutrients, biomass, water and energy, converting by-products and waste into secondary resources, and strengthening competitiveness by lowering unit costs and improving compliance with sustainability expectations in domestic and export markets.

From a scientific standpoint, this topic is relevant because the transition to a circular production model in agriculture requires technological solutions and a system-level understanding of the institutional, organisational, financial and logistical barriers and transition pathways. These remain insufficiently generalised for Ukraine's sectoral conditions. The scientific novelty of the article is threefold.

Firstly, it provides a systematised identification of a key problem of circular transition in Ukraine's agricultural sector. This problem is structured as a coherent set of constraints and risks that hinder the diffusion of circular practices. Secondly, it substantiates and outlines promising directions of transition to circular production as priority pathways for the agricultural sector. These pathways focus on actionable approaches to overcome the identified problems. Thirdly, it establishes a linkage between challenges and solution pathways. This enables the formulation of targeted recommendations. The validity of the proposed scientific solutions is substantiated by their applicability to the decision-making processes within the agricultural sector. The article's problem set and transition directions, which are generalised, provide a basis for the prioritisation of circular measures in the context of limited resources and uncertainty. The structured understanding of barriers and the measures that are employed to overcome them support the design of targeted incentives.

In the context of the emerging green economy, circular production emerges as a novel paradigm within agribusiness, emphasising the optimisation of limited resources and the mitigation of waste generation. The significance of this particular trajectory within the agricultural sector is attributable to the fact that agriculture, being one of the most resource-intensive activities, exerts a considerable impact on the environment. Consequently, 60% of residual agricultural biomass is derived from crop production (Velasco-Muñoz J.F., 2022). The fundamental principle of circular production is predicated on the establishment of self-sufficient cycles, wherein waste generated during one operation is transformed into a valuable resource for another. In the agricultural sector, the organisation of circular production includes the processing of organic waste into compost or biogas, the integration of perennial crops, the integration of crops, and the application of biological methods of plant protection (Perdana T., 2023). These practices aim to conserve resources and are fundamental to the concept of modern development within a green economy. This involves taking a careful approach to the primary production resources of land, water and energy, as well as preserving biodiversity and improving soil fertility (STRATEGY, 2024).

2 Agro-Innovations on the Agricultural Sector of the Economy

The impetus for the advancement of circular production is derived from agro-innovations, which serve as the foundation for enhancing the social, economic and environmental efficiency of business processes within the agricultural sector (Development of the agricultural sector, 2023). The manifestation of these results is evident in four distinct formats: as a process, as a product, as a service, and as a business model. The combination of these innovations ensures a synergistic effect, creating long-term value by extending the product life cycle. The generation of long-term values within a closed production cycle in the agricultural sector has been shown to result in the creation of four distinct types of added value: economic, environmental, consumer and informational (see Figure 1).

In the context of the green economy, a pivotal agro-innovation in the agricultural sector is the agro-ecological approach, which has become an integral component of the organisation of circular production. This approach entails the integration of biological processes into agricultural production. In practice, this approach entails the active utilisation of natural mechanisms of pest control and the cultivation of cover crops, with the objective of retaining soil moisture and enhancing soil fertility (Dovgal et al., 2024). The utilisation of this method has the effect of reducing the use of synthetic chemicals and pesticides. Furthermore, it has been demonstrated to lower environmental pollution and improve product quality. The implementation of this approach has been demonstrated to enhance internal growth potential by optimising resource utilisation and elevating levels of social and environmental responsibility.

To illustrate this point, consider the example of quantitative gains in food production within closed agro-cycles. Such gains have been shown to result in an increase in farmers' profitability by 2-3 thousand US dollars per hectare (Kozyoma, 2024). In particular, the production of biogas from organic waste represents an additional source of income for agricultural producers and a means of reducing dependence on fossil fuels. The use of existing potential makes it possible to produce over 4.2 billion m^3 of biomethane, which could provide As evidenced by Lutkovska (2023), Ukrainian agricultural holdings possess hot water supply systems for their own requirements, in addition to the generation of organic fertiliser (digestate) for domestic agricultural plots. In this context, the implementation of a relevant state policy to stimulate such processes is crucial. This policy should include the implementation of the measures summarised in Table 1.

Digitalisation also plays an important role in organising circular production in agriculture. Today, digital technologies are widely used to monitor soil conditions, manage water resources, and optimise processes, significantly improving the efficiency of agricultural enterprises. Technological innovations such as sensors, drones and precision agriculture systems help to reduce resource losses and increase productivity (see Figure 2) (Value-based imperatives..., 2025).

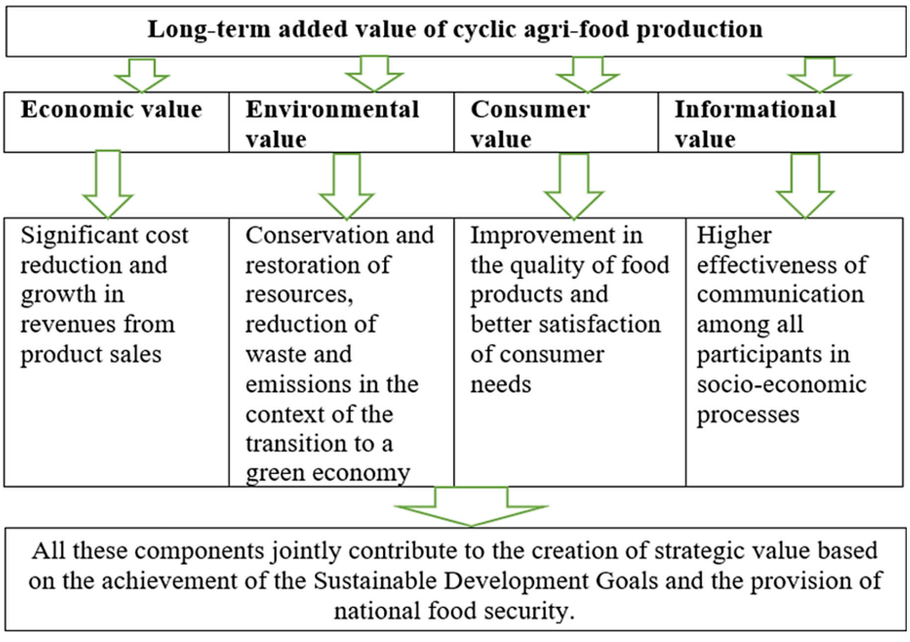

FIGURE 1 Types of value added within the organisation of cyclic agri-food production

Source: developed by the authors

TABLE 1 Directions for stimulating biogas production in Ukrainian households

Direction of state stimulation	Measures	Expected results
Targeted financial support for technical provision	State grants, subsidy programmes, low-interest credit line, tax incentives, etc.	Creation of conditions for the accessibility of technologies for small businesses and household activation of the biogas equipment market
Informational support regarding the feasibility and economic advantages of using biogas	Establishment of online information platforms, advisory centers and training programmes	Dissemination of knowledge about the benefits of biogas, promotion of biogas plant installation
Simplification of administrative procedures for permits and access for state financial support	Optimisation of permitting documentation, introduction of a "single window", creation of a relevant platform in Diia system	Significant reduction of time and financial costs for obtaining permits, shorter investment payback periods
Development of rural infrastructure	Creation of regional networks of service centers, training for personnel	Provision of maintenance services for installations, reduction of operational risks
Creation of domestic market of biofertilisers	Transition to European quality standards, support for local sales	Stimulation of production and consumption of organic fertilisers, expansion of organic production
International co-operation	Attraction of grant funds and investments, exchange of experience	Introduction of new technologies, transition to renewable energy

Source: systemised by the authors

3 Potential of the Agricultural Sector of Ukraine

In the context of the present challenging circumstances pertaining to Ukraine's economic advancement, the agricultural sector is responsible for in excess of 11% of the nation's Gross Domestic Product (Gross Domestic Product, 2024) and provides livelihoods for 41% of the rural populace, constituting over 30% of the aggregate population (Patyka, 2024). The sector's production activities are based on highly fertile chernozem (black soil), and in 2024, agricultural products constituted 60% of Ukraine's physical export volumes (Foreign trade 2025).

Despite the loss of 20% of its territory, Ukraine retains a significant potential for the cultivation of key agricultural crops such as wheat, sunflower, maize, barley and soybeans. The augmentation of their export production has been identified as a primary contributing factor to the stabilisation of the nation's trade balance, which has been in a state of deficit since 2006 and underwent a marked deterioration during the period of Russian aggression. In 2024, the

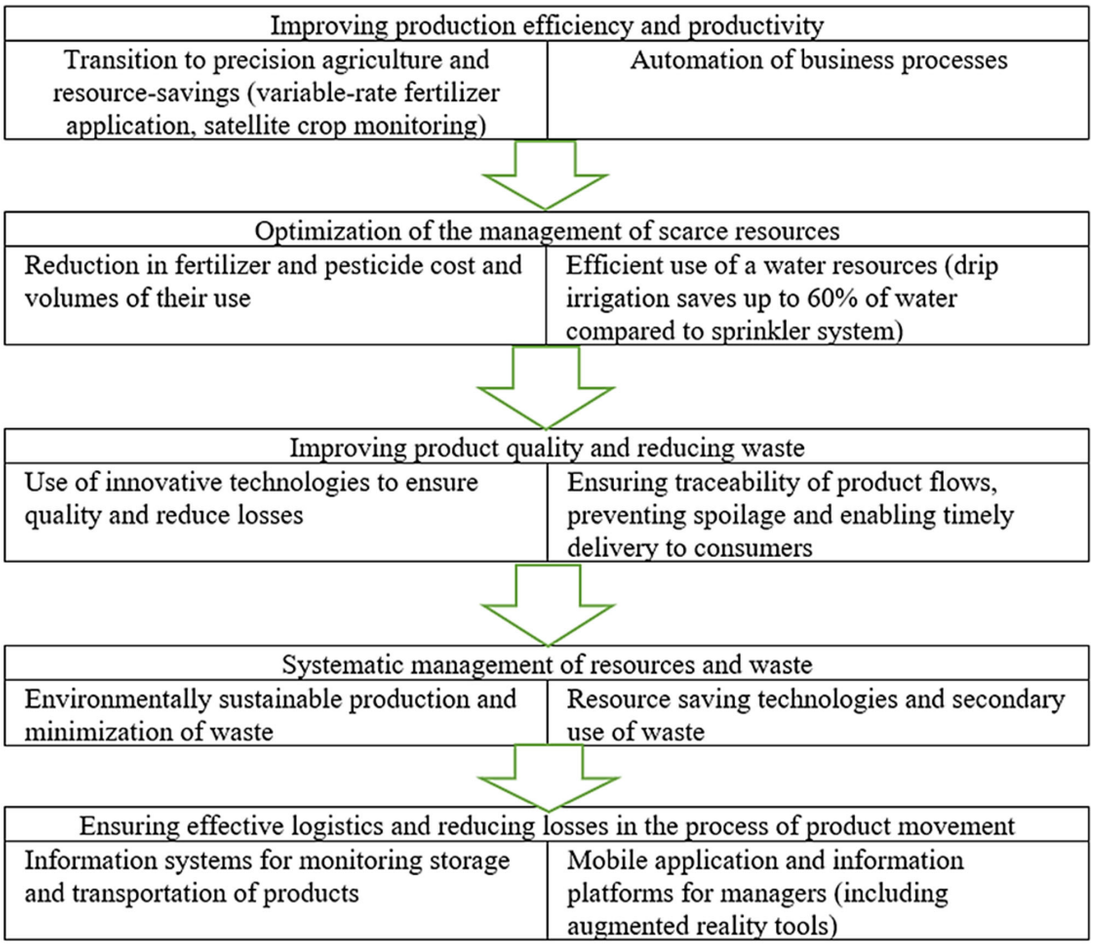

FIGURE 2 Opportunities of digitalisation for closed-loop cyclic production

Source: systemised by the authors

trade balance deficit stood at -18.9%, in comparison to -1.1% in 2021 (Foreign trade balance, 2025). Concurrently, the sector has experienced a notable augmentation in the export potential, which has precipitated a substantial escalation in the production of major agricultural commodities, including wheat, maize, barley, sunflower, and soybeans. Consequently, the gross value added of the sector's products increased almost sevenfold between 2010 and 2021 (Agriculture of Ukraine, 2022). This growth was driven by the introduction of advanced technologies and innovations, which improved production efficiency and product competitiveness in world markets.

However, the war has had a negative impact on the sector's performance. According to estimates by the Tony Blair Institute, due to land contamination by mines and explosive remnants of war, Ukraine annually loses 11.2 billion USD in GDP, 8.9 billion USD in export revenue and 1.1 billion USD in local budget tax receipts compared to 2021 (Agapova V., 2025). Direct losses account for 12% of total losses, of which 56.7% are agricultural machinery (Roman Neyter, 2024). It is estimated that 19.5% of agriculture storage capacity has been lost (Damages, 2024). In order to reduce losses in the form of waste in vegetable production, it is estimated that demand for potato and vegetable storage will be 10-20 thousand tonnes of capacity for each district centre and area near regional centres (Key challenges, 2025).

Notwithstanding the challenges posed by the war, statistical evidence suggests the resilience of Ukrainian agribusiness. In 2024, export growth (41 billion USD, +13.4%) was associated with the restoration of maritime corridors (89% of exports in 2024), which became possible due to international support and initiatives such as the "grain corridor" (Khotsky, 2025). As reported by the Ministry of Agrarian Policy and Food, in 2024 Ukraine almost attained the pre-war level of agri-food exports, with a value of 24.5 billion USD, accounting for 59% of total exports. Concurrently, exports of finished products have decreased by 31.1% compared to imports of such products. This scenario is economically untenable, resulting in the export of value added from the national economy.

4 Transformation Challenges and Circularisation Prospects

Given the above-mentioned potential, the sector still facing the problem of transforming traditional model of agribusiness, which is based on linear resource use ("production-consumption-disposal"), and which is becoming increasingly ineffective, due to a number of nowadays challenges, including:

1) Intensification of production and resource deficit

Production intensification allows for 2-3 times more output per hectare than extensive farming, but simultaneously creates a problem of resource scarcity. Over the past 30 years, the world has lost around a third of its arable land – approximately 430 million hectares. Since Ukraine launched its agricultural market, the area of agricultural land has decreased by 1% (Development of agricultural sector..., 2023). The limited availability of land, water and energy resources necessitates a re-evaluation of approaches to their utilisation, particularly in light of the projected decline in the annual growth rate of global agricultural production. Current projections indicate a decline from 2.2% in the past decade to 1.5% by 2030 and to 0.9% between 2030 and 2050 (T. Jelle Bruinsma, 2024).

A salient difference between Ukraine and EU countries is that short-term gains frequently predominate in Ukraine, a phenomenon often referred to as "squeezing the maximum out of the soil". This has resulted in a humus loss of 0.1% per year. A s posited by the specialist at the Institute for Soil Protection of Ukraine, the restoration of soil fertility strategy through crop rotations, green manure and organic farming would require an additional 14.2 billion UAH.

2) Environmental impact

Agricultural production is a significant source of greenhouse gas emissions (approximately 20%), soil and water pollution, and large volumes of organic waste. In Ukraine, there is a significant number of livestock farms and complexes with an annual manure output of approximately 335 million m^3, containing up to 1.5 million tons of nitrogen. It has been determined that, during storage, transportation and disposal, more than 10% of this nitrogen penetrates the surface and groundwater. Consequently, nitrate pollution has been found to result in the annual release of approximately 450 thousand tons of nitrogen compounds into the environment, thereby leading to ecosystem degradation (Shuvar, 2022).

3) Economic instability

The sector is characterised by a high degree of seasonality and vulnerability to climate risks. Despite the fact that Ukraine is among the countries with the lowest overall exposure and vulnerability of multi-sectoral development to climate change (Byers et al., 2018), annual food damages may increase fivefold by the 2050s and seventeen-fold by 2080s, which underlines the need to build resilience to flooding (Nicklin, 2019). In 2025, Ukrainian farmers confronted mounting production costs, attributable to a confluence of economic factors. Specifically, there was an increase in the cost of seeds of 10%, and in the cost of crop protection products of 10-15%, as a consequence of inflation and exchange rate volatility. A gradual increase in the excise tax on fuel may result in a price increase of approximately 10%, which would lead to an additional expense of 5.7 billion UAH for farmers. Consequently, the cost of mineral fertilisers increased by 10-15%, due to inflationary processes and logistic disruption caused by the war (Forecast for 2025). The devaluation of the hryvnia and labour shortages have had a deleterious effect on the agricultural sector, forcing agribusinesses to increase wages for skilled workers.

4) Social challenges

In many regions, employment in agriculture has declined due to automation, which has the effect of exacerbating social inequality and demographic problems. Moreover, the Ministry of Agrarian Policy has reported that approximately 200,000 agricultural workers are currently serving in the Armed Forces of Ukraine. This has resulted in a significant exacerbation of the staffing deficit within the sector (Served in the Armed...).

Consequently, the agricultural sector of Ukraine's economy is experiencing considerable damage as a result of Russian aggression and disruption of production chains. Consequently, the post-war recovery of the region necessitates the incorporation of innovative practices and the implementation of circular production models.

The global experience is highly relevant in this context. For instance, the Netherlands and Sweden have been demonstrated to utilise their limited agricultural resources in an effective manner. The Netherlands has implemented a sophisticated system of closed water cycles in agriculture, enabling up to 90% to be reused and reducing water consumption by 50-70% compared to traditional methods (Gonzalez-Martinez et al., 2021). It is important to note that irrigation accounts for approximately 70% of total water usage in agriculture on a global scale (Juan F. Velasco-Muñoz et al., 2019).

Moreover, the experience of Sweden in the implementation of precision agriculture is of no less importance for Ukraine's future agricultural development. The utilisation of sensors, satellite imagery and drones to monitor and assess soil and crop conditions has resulted in a 20-30% reduction in fertiliser costs and a 10-15% increase in yields (Ludvig Dietmann, 2020). The digitalisation of agricultural business processes facilitates the precise determination of fertilisers and pesticides required for individual plots, thereby reducing their utilisation and enhancing soil fertility.

In the context of this study, it is also pertinent to draw upon the experience of Denmark and France with regard to waste processing and management. These countries are at the vanguard of the utilisation of organic waste for the purpose of biogas production. Denmark, particularly in rural areas, relies on co-operative schemes for processing organic waste from farms, the food industry and households. In contrast, France is actively developing urban biogas plants that process organic waste from major cities such as Paris. These plants are capable of producing biogas, which can then be utilised for various purposes, including powering public transport and heating residential buildings (Dovgal et al., 2024). It is estimated that approximately 35% of total energy consumption in the food sector is attributable to crop production. The establishment of an extensive network of waste-processing facilities for biogas has the potential to contribute to soil restoration and reduce dependence on external resources. This is due to the fact that the technology of organic waste conversion into biogas also produces organic fertilisers, thereby reducing the negative effect of waste accumulation. Moreover, the implementation of French agroforestry practices has been demonstrated to enhance ecological balance, thereby facilitating effective control of soil erosion and improving soil structure (Noémie Hotelier-Rous et al., 2020). This, in turn, has been shown to enhance fertility and moisture retention, support biodiversity, and create new ecological niches for local flora and fauna.

The European experience in this domain is noteworthy for the establishment of composting stations, which facilitate the conversion of organic waste into high-quality compost for soil fertilisation (Cristiano, 2021). This approach is less capital-intensive, yet it not only curtails the volume of waste requiring disposal; it is also oriented towards the production of organic fertilisers, thereby diminishing the reliance on chemical fertilisers. Consequently, the cost of fertilisers is reduced, production costs are decreased, soil fertility is enhanced, and the risk of environmental pollution is diminished. Ukraine is already actively adopting the practice of using waste as an alternative fuel, which reduces the consumption of traditional resources.

The implementation of these directives necessitates the establishment of agricultural co-operatives for the joint utilisation of machinery and waste management facilities. This approach has the potential to reduce costs and mitigate environmental impact. In this process, the support of local self-government bodies, the development of public-private partnership projects for the introduction of innovative soil tillage and waste management technologies are important, as they reduce costs and production efficiency. The establishment of local clusters and co-operatives is hypothesised to assist farmers in the collective utilisation of resources, including machinery and equipment. This collaborative approach is predicted to result in cost reductions and facilitate access to novel technologies (Development of innovation..., 2023). The conceptualisation of a system of financial and tax incentives for cluster projects is poised to facilitate the restoration of production capacities, ensuring their resilience and efficiency (Lagodienko, 2024).

The development of a circular production model in the agricultural sector has emerged as a strategic imperative for Ukraine, particularly in the context of sustainable development and post-war recovery. The institutional framework that has already been established is the facilitating factor in this process (About approval..., 2017; About management..., 2023), The programme provides financial assistance to farmers who adhere to organic production practices, encompassing the utilisation of natural fertilisers and biological methods for pest management. This approach has the dual benefits of reducing chemical usage and enhancing soil quality.

Among the main priority directions of the development of circular processes in the agricultural sector at a present stage, the following can be distinguished:

- Formation of a system of incentives for the transition to organic production based on the use of organic waste as a source of fertilisers for crops and livestock production;
- development of infrastructure to maximize the life cycle of the materials, raw materials and products in the agricultural sector;
- creation of technological opportunities for closed-loop use of urban and rural wastewater for irrigation based on advanced purification technologies;
- use of biomass from plant and animal waste for the production of biofuel and organic fertilizers;
- formation of logistic cycles for closed agro-cycles;
- support by the state and local self-government bodies for the further development and certification of organic agricultural production;
- restoration of natural ecosystems, including land resources and biodiversity;
- stimulation of bioenergy production in rural areas;
- support for the transition from sprinkler to drip irrigation;
- development of new eco-product designs and innovative marketing solutions.

These priorities reflect two interrelated cycles: the technological and the biological. The first of these concerns the processes of maintenance, return, renewal, reuse and recycling of materials in the production process. The second restoration value from waste is pivotal in ensuring the regeneration of biological assets and ecosystem components, particularly soils. The objective of their implementation is twofold: firstly, to reduce dependence on fossil fuels,

and secondly, to mitigate greenhouse gas emissions. This is of particular pertinence in the context of facilitating the transition of small and medium-sized farms to a circular economy. This transition can be supported through the provision of grants, the implementation of programmes, and the offer of compensations. The purpose of these measures is to stimulate co-operation among farmers and to develop local markets (The state is expanding..., 2025). These measures provide financial assistance for the implementation of environmentally sustainable technologies and methods in agriculture, including precision farming, agroforestry and integrated water-resource management. In conclusion, it is evident that the implementation of cyclical practices, the reduction of environmental impacts, and the enhancement of resource-use efficiency are instrumental in establishing the foundations for the sustainable development of the agricultural sector.

In the context of the contemporary intricate economic environment, the transition to a circular economy in agriculture can be facilitated through two forms of governance: state-based and network-based. In this context, the principle of a strong state, the active involvement of stakeholders, and an openness to network governance are of paramount importance (Cramer, 2022). According to the Ellen MacArthur Foundation, the transition to a circular, closed-loop food economy by 2050 has the potential to generate significant economic benefits, estimated at 2.7 trillion USD (Tansy Robertson-Fall, 2021). Furthermore, this transition is predicted to create an additional 100,000 jobs by 2030, increase farmers' profits by 3,100 USD per hectare, and generate savings of approximately 550 billion USD in healthcare costs (Velasco-Muñoz, 2022). Consequently, a fundamental characteristic of a circular agroeconomy is its capacity to generate long-term added value and conserve resources.

5 Conclusions

In the context of developing a green economy, the primary goal of the circular economy is to ensure sustainable development by optimising the use of limited resource potential and innovative business models, underpinned by systemic state support. The analysis of the challenges and opportunities associated with Ukraine's agricultural sector transitioning to cyclic production indicates that the implementation of circular production models has the potential to contribute to both ecosystem restoration and the economic growth of agricultural enterprises.

Using resource-efficient technologies, such as closed water cycles, precision agriculture and waste processing, significantly reduces production costs, increases productivity and creates new jobs. A post-war agro-ecological development strategy for the state should stimulate biological processes in agricultural production and minimise the use of synthetic fertilisers and pesticides, thereby reducing environmental damage and improving product quality. Using resource-efficient technologies such as closed water cycles, precision agriculture and waste processing significantly reduces production costs, increases productivity and creates new jobs. An agro-ecological development strategy for the state after the war should stimulate biological processes in agricultural production, minimising the use of synthetic fertilisers and pesticides and reducing environmental damage while improving product

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