

CURRENT STATE AND DIRECTIONS OF FURTHER CIRCULAR AGRICULTURAL ECONOMY DEVELOPMENT IN UKRAINE

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Abstract. *The subject of the study* is the analysis and development of the circular agricultural economy of Ukraine. *Methodology.* The study uses general scientific methods, in particular: theoretical generalisation; methods of positive-normative analysis and statistical analysis. *The purpose* is to assess current trends in the circular economy in the agricultural sector of Ukraine and to substantiate the directions of its further development. *Research conclusion.* Achieving the global sustainable development goals, to which Ukraine has joined, requires the search for and implementation of new business models aimed at ensuring the interests of current and future generations. The agricultural sector is of utmost importance in addressing these challenges, as it contributes to solving the problem of hunger, ensuring food security and improving the quality of life of the world's population. The article provides an overview of the current problems of development of the agro-circular economy, which is proposed to be considered as one of the tools for achieving the goals of sustainable development. The main problematic aspects that impede the intensification of agro-circular transformations in Ukrainian agriculture are identified. The article compares certain indicators of the level of agro-circularity in the EU and Ukraine. An analysis of the current state of development of the circular economy in Ukrainian agriculture is carried out. On the basis of economic and statistical models, the level of dependence of agricultural production on the use of new material resources is studied. The obtained results show low rates of development of circular processes in the agricultural sector of Ukraine and a high level of consumption of input resources. The study of the methodological basis for assessing the state of development of the closed-type agro-economy has allowed to propose the authors' vision of systematisation of indicators of the level of development of circular processes in agriculture. This systematisation was based on the identification of five main dimensions: consumption of new materials, waste volumes, agricultural waste management, economic efficiency, and state financial support. The study identified key priority areas for further development of the agro-circular economy in Ukrainian agriculture.

Key words: agriculture, closed economy, sustainable development, resources, agricultural companies, agro-circular processes.

JEL Classification: Q15, Q01, O13

1. Introduction

According to the FAO, the world population is expected to grow by about 30% by 2050, requiring a 60% increase in food production (FAO, 2009). The consequences of active anthropogenic human economic activity have led to climate change, which already poses significant challenges and threats to agricultural production and the environment (Murray et al., 2015). The limitation of natural and biological resources and the complex nature of their

reproduction have led to an understanding of the inadequacy of traditional linear agricultural production models, which can no longer provide solutions to the acute socio-economic and environmental problems facing society. Humanity is gradually coming to a global understanding of the feasibility of developing and implementing new models of agro-economic relations based on the principles of saving resources, reusing them, limiting the amount of waste and finding alternative ways to

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create long-term value, taking into account the preservation of natural and biological potential. One such innovative model is the agro-circular model, which focuses on activities within closed agricultural production cycles. Today, scientists agree that circular economy models promote economic and environmental sustainability and are promising from a strategic management perspective (Toopa et al., 2017).

In contrast to its traditional format, the agro-circular model of the economy focuses on minimising the cost of acquiring new resources and is based on the logistical production chain: agricultural production – agricultural processing – agricultural conservation (Garrett et al., 2020). The intra-cyclical economic agro-processing of waste and its repeated use as a resource is the main feature of the cyclical model of agriculture. The annual increase in the amount of waste in EU countries leads to excessive environmental pollution, causing significant damage to natural resources and making it difficult to achieve sustainable development goals (Königer et al., 2021).

Increasing land use intensity leads to loss of biodiversity. In addition, the active use of chemical defences, feeding and artificial breeding of livestock leads to the inevitable loss of their natural genetic potential. This in turn significantly limits the food potential of high quality, safe and organic food of animal origin (Abdi et al., 2021). Bradshaw et al. (2021) identify a problem of instability in the agricultural sector and propose replacing it with more optimal and neutral natural resource potential models of closed production. Helgason et al. (2021) note that despite the active practice of transition to the principles of a "green" economy, most modern methods of agricultural production are the main factors of climate change, resource consumption and greenhouse gas emissions. In this context, a set of measures aimed at developing a circular agricultural economy based on closed cycles and agricultural value chains is being developed on the agenda of the standard European agricultural policy, which will contribute to the transition towards sustainable agri-food systems and ensure strategic food security.

2. Theoretical Aspects of the Development of the Circular Agricultural Economy of Ukraine

In the agricultural policy practice of the EU countries, increasing the level of circularity in agriculture is a key strategic development task within the accepted course of the "green" economy. The critical tasks of increasing the level of circularity of agricultural processes are to reduce the burden on natural and biological resources, to prevent the loss of biodiversity, to create conditions for sustainable

growth and to increase the level of employment of the rural population (EU Commission).

The relevance and strategic importance of addressing the challenges of sustainable development has led to an increased interest in justifying closed-loop models for agriculture. Rauw et al. (2023) see circular agriculture as the closing of food cycles and the reduction of dependence on external resources. The authors provide a basic principle for the construction of a promising circular model: "bees – legumes – poultry". The result of such a model was to improve the supply of feed resources to the industry, optimise land use and maximise the reuse of natural and biological resources of the farm. Other models of agro-food production in crop production are based on the principles of building closed cycles (Klein et al., 2022).

An agri-economic model similar to the basic principles of circularity was proposed by the model of reusing biowaste, by-products and biomass for cattle feed. This made it possible to increase the sustainability indicators of the industry and reduce the competition between feed and food (Van Zanten et al., 2016).

Donner et al. (2021) have made important developments and strong results, proposing six agro circular economy models and developing their typology in their scientific work. The authors identified increasing the value of agro-food waste as the primary objective of these models. Critical attention in the modelling process was paid to biogas production as one of the most promising areas of development of closed cycles in agriculture.

Based on models of the agro-circular economy, Teigiserova et al. (2020) look at waste management in the agricultural and food industries. The authors propose a new classification of food waste, including "leftovers", "waste" and "losses". Based on the construction of a hierarchical waste pyramid, the scientists have developed a circular management model that closes the loop in the agri-food supply chain.

The circular economy model of the agri-food sector proposed by Lüdeke-Freund, Gold and Bocken (2019) is already widely known. The basis for the construction of these closed-loop models is the division of raw materials into three main types: cascade raw materials, processed raw materials and organic raw materials.

The principles of circularity in the agri-food sector are attracting more and more attention from scientists and practitioners. Scientists determine that in order to implement them in the practical activities of farms, it is necessary to create new opportunities for finding new management solutions that should be strategically focused on increasing added value in the agri-food sector to ensure growth in food production and effective waste management (Salimi, 2021).

Boer & van Ittersum's (2018) agro-circular system models are based on the following principles: bioproducts produced in crop production should be the basis for human nutrition and food production. Crop and livestock by-products and food waste should be returned to the closed agri-food system.

Navarre (2021) concludes that in order to build effective circular models of agricultural products, it is necessary to ensure high speed and productivity of the transformation of biological resources and optimise the cascade process of their life cycle, the final stage of which should be the return to the biosphere.

In line with this, the authors note that there is currently a need to increase the available research results in the direction of developing agro-circular models and agricultural development scenarios (Velenturf et al., 2019). According to Jurgilevich et al. (2016), social and environmental aspects of building closed agri-food cycles remain important unresolved issues.

Studying the methodological basis for assessing circularity in agriculture, the authors emphasise the need to take into account the specificities of this type of economic activity: the production of goods with a short shelf-life, a close link with natural processes, the seasonality of production and the number of production cycles in crop and livestock production (Velasco-Muñoz et al., 2021).

This article aims to assess the current trends in the development of the circular economy in the agricultural sector of Ukraine and identify areas for further development. Accordingly, the study identified the following key objectives:

1. Analysis of indicators of the current development of the agro-circular economy in Ukraine.
2. Adding methodological foundations for assessing the development of circular processes.
3. Identification of priority strategic directions for enhancing the development of Ukraine's agro-circular economy.

3. Analysis and Strategic Vectors for the Development of Ukraine's Circular Agricultural Economy

Ukraine's agriculture is a key sector of the national economy, whose development and efficiency largely determine the country's food security potential, the level of welfare of the population and the ability to achieve sustainable development goals. In recent years, under martial law, the agricultural sector has become the only type of economic activity that shows signs of sustainability, is profitable and continues to provide foreign exchange earnings to the Ukrainian economy. At the same time, maintaining this trend requires the introduction of transformational changes in the organisation and

management of agricultural production that will meet modern requirements and trends in agricultural development in Europe. In particular, in order to ensure the strategic competitiveness of Ukrainian agricultural and food products, it is crucial to take into account the principles of safe production of quality products and maximum conservation of natural and biological resources, the quantity and quality of which determine the future agricultural potential of Ukraine.

Ukraine has a strong agrobiological production resource potential, which is determined by the area of agricultural land of 41.3 million hectares, 853 thousand hectares of perennial plantations, 2.6 million heads of productive cattle, 5.6 million heads of pigs, 1.1 million heads of sheep and 202.2 million heads of poultry (Agriculture of Ukraine, 2021). At the same time, over the past decades, agricultural production has been characterised by a consumerist approach to resource management, which has led to a loss of natural and biological potential and a significant deterioration in its quality component.

These complex trends have led to the need to revise and change the principles of management in agriculture and the exceptional need to preserve and restore the industry's natural resources.

The main problems that currently necessitate the implementation of agro-circular economy principles in Ukrainian practice include the following:

1. High dependence of agriculture on non-renewable resources (land, water).
2. The limited and non-renewable nature of the main component of the agricultural resource potential – land resources, the quality of which has deteriorated significantly over the past 30 years.
3. Traditional problems of the Ukrainian economy include dependence on energy imports and low energy security (especially in the context of the ongoing military conflict).
4. Increased pollution of rural areas due to unprocessed organic waste and lack of infrastructure for the disposal and processing of agricultural waste.
5. Openness of agricultural production cycles and low awareness and popularity of the agro-circular economy concept.
6. Low level of organisational culture of agricultural management in most small and medium-sized agricultural companies.
7. The dominance of the financial priority of maximising profits in the short term among owners of agricultural capital.
8. Loss of biodiversity and significant reduction in the number of farm animals.
9. There is a growing unemployment rate in rural areas and significant inclusive gaps between the welfare of the population in rural and urban areas of Ukraine.

One of the main strategic reasons for intensifying circular transformations in the agro-economy is the need to improve the sustainability of agriculture and rural areas. Achieving the Sustainable Development Goals set by the Government of Ukraine in the context of further European integration requires a sustainable food system, reduction of harmful emissions, conservation of natural resources and creation of long-term agricultural values for the benefit of current and future generations. All these are signs of the agro-circular economy, which, according to the authors, can be considered a vital tool for solving the problems of sustainable development of agriculture and rural areas of Ukraine.

The analysis shows that, despite the commitment to the green economy and the transition to sustainable development in the EU, agro-circular transformations are taking place at a relatively slow pace. The level of production and consumption of mineral fertilisers has hardly changed over the past ten years. The largest consumers of mineral fertilisers among European farmers are those in Germany, France and Poland. In addition, these

countries have the highest consumption of crop protection pesticides. Italy, the Netherlands and Spain were also active consumers in this group in 2021. These countries are the leading agricultural producers in the EU and have about 51% of the EU's agricultural land (Eurostat, 2021).

In Ukraine, the problem of using mineral fertilisers and chemicals in agriculture is extremely relevant. Despite the intensification of initiatives to improve the sustainability and circularity of agricultural production, no significant progress has been made in this regard. In recent years, the amount of new resources consumed in crop and livestock production has been steadily increasing. This includes the increased use of mineral fertilisers and pesticides. The total share of fertilised agricultural land is over 92%. About 142 kg of mineral fertilisers are applied per hectare, and the total volume of fertilisers used has a steady upward trend and exceeds the volume of mineral fertilisers applied in most European countries (Figure 1).

Waste management is also a significant challenge for the development of a circular economy in

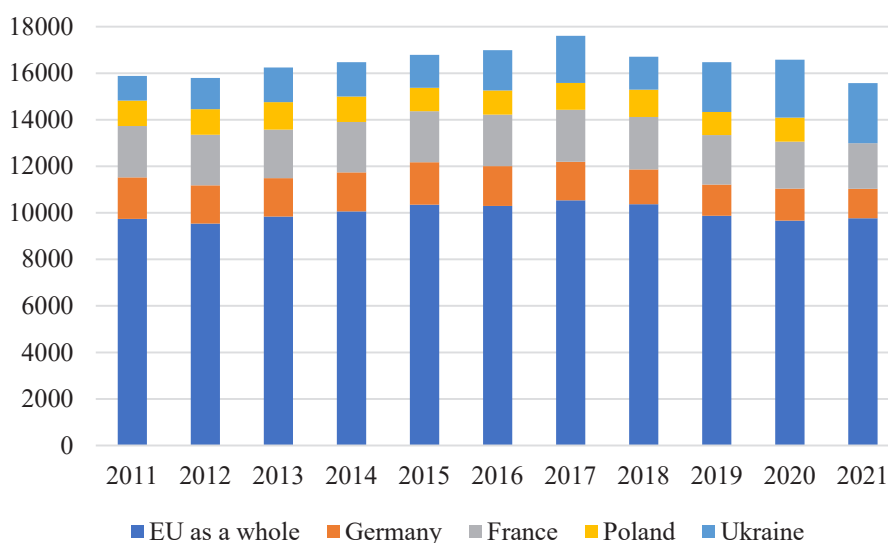


Figure 1. Volumes of mineral fertilisers used in agriculture, million tonnes

Source: built by the authors in accordance with: Agriculture of Ukraine (2021), Eurostat (2021)

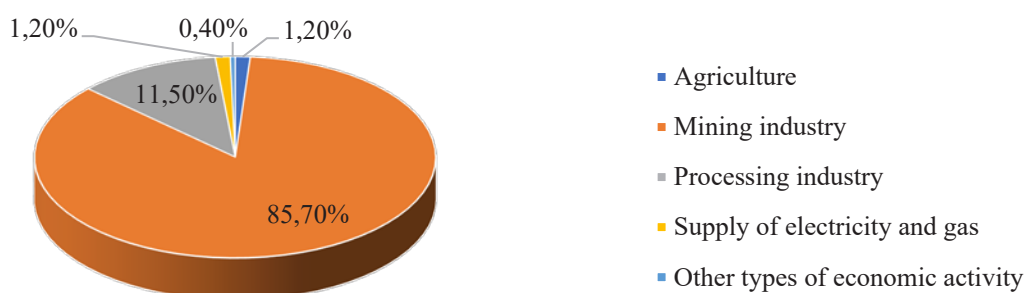


Figure 2. Share of Ukrainian agriculture in waste generation by type of economic activity, %

Source: built by the authors in accordance with: Environment of Ukraine (2021)

Ukraine's agricultural sector. The lack of appropriate infrastructure and insufficient waste management culture among the population and business entities has led to the accumulation of waste in the sector over the years. At the same time, studies have shown that the share of agricultural waste is insignificant on a national scale – about 1.2% (Figure 2). However, the absence of a balanced waste management policy in the agri-food sector over the years has created a significant threat to the achievement of sustainable development goals and food security in the country. In this context, the problem of agricultural waste management and utilisation is a dangerous one. The main areas of agricultural waste disposal include discharges of hazardous substances into water resources and storage on land plots not intended for this purpose. The share of agricultural waste buried in the natural environment is over 70%. About 22% of waste is utilised in various ways. Some waste remains on the territory of agricultural enterprises and leads to a deterioration in the quality of land resources.

The problem of waste management and recycling is currently very relevant for Ukraine's economy and needs to be addressed immediately. Historically, one of the major obstacles to solving this problem has been the need for additional financial resources. The costs of waste management in the agri-food sector are borne by the state and local authorities. The limited state and local budgets determine the final principle of financing environmental protection measures, the amount of which must be increased to protect and restore the environment (Figure 3).

Total expenditures on environmental protection measures in the sector amounted to 1,003 billion USD, and capital investments amounted to 472 million USD. The main areas of investment in the development of cyclic processes include wastewater collection and disposal and waste collection and disposal. The low level of social responsibility of agribusiness and the culture of consumer behaviour in Ukraine today do not contribute to additional funding for waste management.

This once again emphasises the need to create closed production cycles within the agri-food sector, which can create preconditions for solving this problem and transitioning production to the principles of circular development. At the same time, the results of the analysis show that the pace of development of circular transformations in agriculture remains slow, and the indicators of the burden on the resource and biological potential of the agricultural sector are characterised by a clear upward trend (Table 1).

The results of the study showed that the level of development of circular transformation in agriculture in Ukraine is low, and the pace could be faster. Despite the highest level of ploughed agricultural land in Europe and a sharp decline in biodiversity, circular processes in the agricultural sector have not yet become widespread. Every year, the production and consumption of new material and technical resources by agricultural production (in particular, chemicals) is increasing, and the area under mineral fertilisers and pesticides is growing. In order to ensure the reproduction of the natural resource potential of the agricultural sector, it is necessary to increase the amount of expenditures by agricultural enterprises for the restoration of natural and biological resources. At the same time, during the hostilities, the agricultural sector demonstrated an increase in the leading performance indicators in Ukraine's economy and generated more than 20% of gross value added.

One of the reasons for the slow development of circular processes in modern agriculture in Ukraine is the active hostilities that create increased risks and threats to business in the agricultural sector as a whole. In such circumstances, farmers are trying to minimise them, cut costs as much as possible and intensify agricultural production using the cheapest possible inputs and materials. In the current realities of the Ukrainian agricultural economy, such materials are chemicals that are traditionally used in agribusiness practice and do not require the organisation of new agro-industrial value chains based

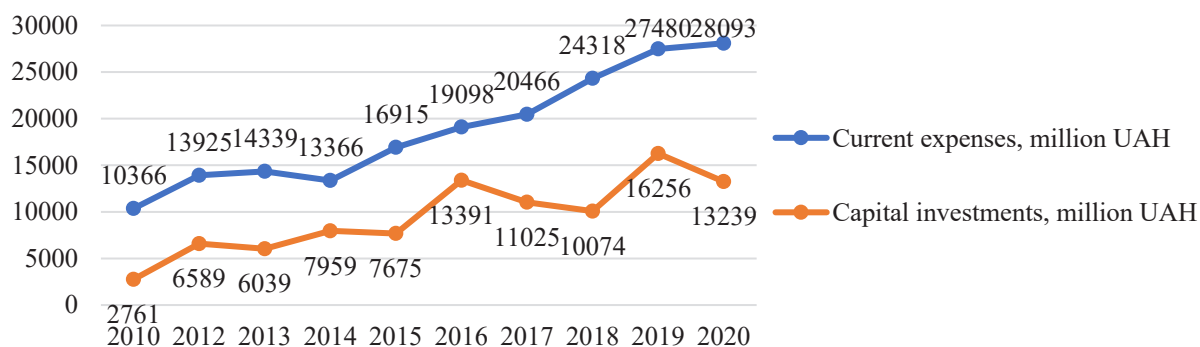


Figure 3. Expenditures on the protection and reproduction of natural resources in Ukrainian agriculture, million UAH

Source: built by the authors in accordance with: *Environment of Ukraine (2021), Agriculture of Ukraine (2021)*

Table 1

Indicators of the state of development of the circular economy in Ukrainian agriculture

Indicators	2000	2010	2015	2018	2020	2021
<i>Environmental component</i>						
Percentage of ploughed agricultural land, %	77,8	78,1	78,4	79,1	79,5	81,0
Amount of mineral fertiliser applied per 1 ha, kg	60	84	98	134	152	142
Area treated with pesticides, %	28,5	37,7	42,6	89,5	91,4	91,5
Production of chemical products for industry outside Ukraine, thousand tonnes						
Including urea (with nitrogen content)	2470	2285	984,3	422,7	786,8	1159
Ammonium nitrate	842,1	510,2	360,9	362,3	548,2	541,9
Biodiversity conservation, thousand heads (cattle)	9423,7	4494,4	3750,3	3332,9	2874,0	2644
Expenditures on biodiversity conservation, million UAH	-	236,4	298,2	378	956	968
Expenditure on soil restoration, million UAH	-	236	561	1153	1584	1577
Carbon dioxide emissions, thousand tonnes	552,0	718,1	1110,4	1174	1187,5	1461,8
Share of water used for production needs in agriculture, %	23,6	26,4	20,3	24,5	21,8	22,2
Share in industry GDP, %	8,4	8,2	11,9	10,2	9,3	10,1
Gross value added of industry, billion USD	5,4	10,4	10,9	13,3	14,4	20,7
Share in total value added in the economy, %	16,3	8,3	14,2	11,9	10,8	12,4
Trade openness (share of exports), %	8,5	14,3	31,8	33,0	38,3	41,2
Grain yield, q/ha	18,3	27,6	43,8	52,2	46,1	53,9

Source: calculated by the authors in accordance with: *Agriculture of Ukraine (2021)*

on the principles of a closed cycle. For Ukrainian farmers today, building new organisational forms and mechanisms based on the principles of the agro-circular economy is a complex and costly issue that requires changing partners, establishing new economic ties and significant capital investments. Given the unstable economic and political environment, this task is complicated by high interest rates on bank loans, unstable economic relations with partners and the need for clear strategic guidelines for agribusiness development.

Taking into account the listed complex prerequisites for intensification of agro-circular transformations in Ukrainian agriculture, the authors made an attempt to analyse the level of dependence of the agrarian economy on the costs of production resources. The determining criterion was the level of material intensity of agricultural production. The analysis of the financial statements of 165 small and medium-sized agricultural enterprises showed a high dependence of the traditional linear form of agricultural production on the cost of production resources. A simple mathematical model of linear regression on two convincing features was used as a specific methodological technique of the economic and statistical method. Based on the impact of material costs on the value added of agricultural production, the regression coefficient was 88%, and based on the value of output – 99%, respectively. The mathematical models in the two respective cases are as follows: Linear regression equation model.

By the degree of influence of material resource costs on value added:

$$Y_i = 46054 + 0,48x_{ij} \quad (1)$$

where Y_i is the amount of gross value added per 1 agricultural enterprise, thousand UAH;

x_{ij} is the amount of material costs per 1 agricultural enterprise, thousand UAH.

A model of a linear regression equation by the degree of influence of production resources on the cost of agricultural products as follows:

$$Y_i = 31025 + 1,56x \quad (2)$$

where Y_i is the value of output per 1 agricultural enterprise, thousand UAH;

x_{ij} is the amount of material costs per 1 agricultural enterprise, thousand UAH.

The results indicate a high dependence of the current form of (linear) organisation of agricultural production in Ukraine on inputs. This dependence is inherent in most agricultural enterprises in the country today. At the same time, research has shown that Ukrainian large agricultural holdings are actively developing the processes of creating new closed cycles of agricultural production. In particular, fast cycles based on new technological solutions in biogas production are the most popular. For example, in 2022, the Ukrainian concern MHP received a global award from the World Biogas Association (WBA) for its participation in the AD and Biogas Industry Awards 2022. The new solutions are technologies for creating a circular cycle based on the processing of poultry waste into biogas and organic fertilisers.

The research has shown the exceptional importance of actualising and accelerating the pace of agro-circular transformations for the further development

of agriculture in Ukraine. At the same time, the study identified a significant problem in the formation of a set of indicators that can be used to assess the level and effectiveness of circular transformations in the agricultural sector. The existing methods and tools for such an assessment are diverse, often unrelated and do not reflect the national peculiarities of monitoring and evaluation of the sector. In this regard, based on the study of scientific literature, existing methodological provisions and their own scientific and methodological developments,

the authors of the article tried to outline a set of indicators for assessing the level of development of circular processes in Ukrainian agriculture. The corresponding set of indicators is proposed to be systematised into five assessment dimensions: consumption of new materials, waste volumes, agricultural waste management, economic efficiency, and state financial support (Figure 4). The authors believe that the presented system of indicators will be useful for further research and effective monitoring of the state of development of agro-

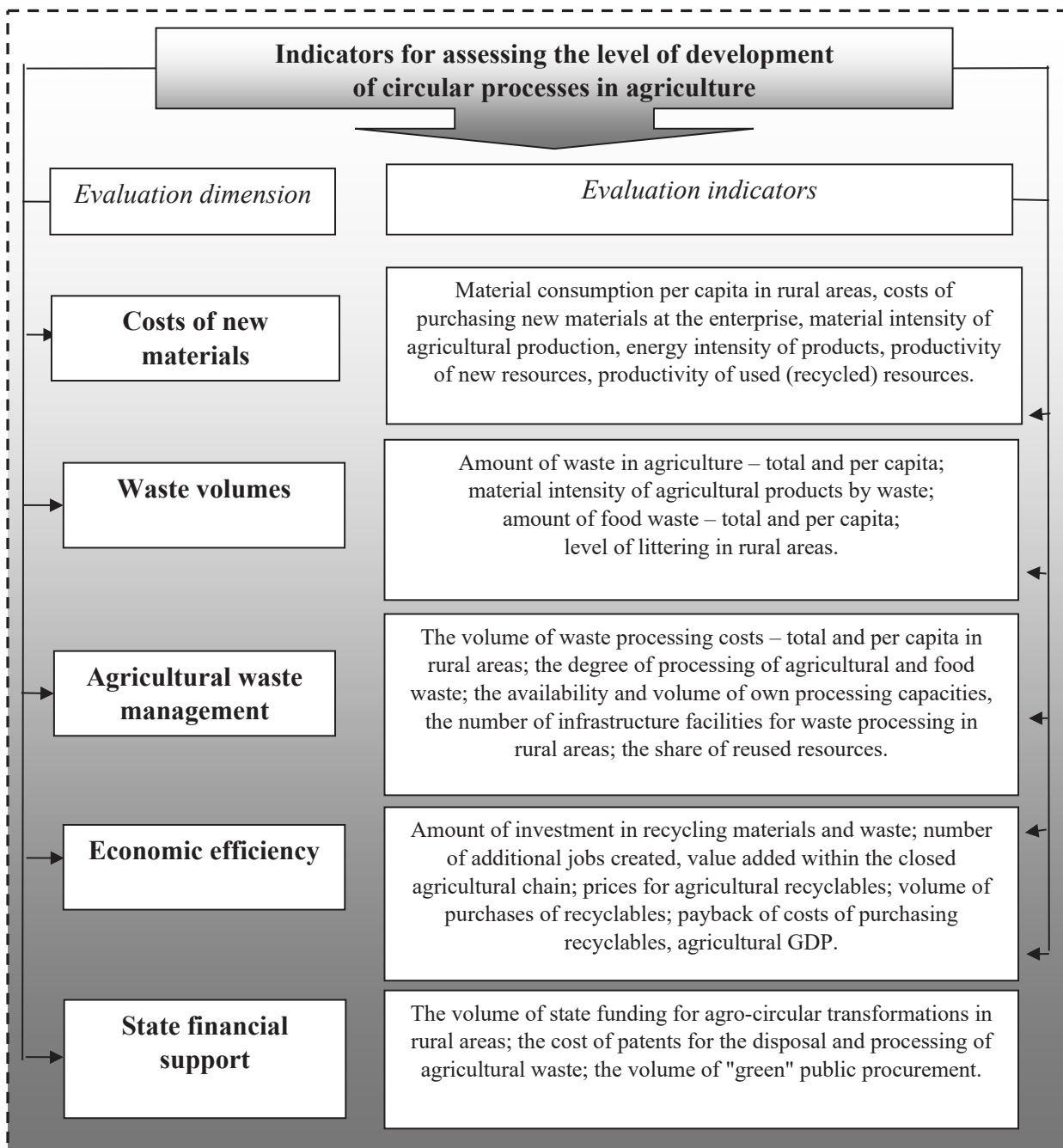


Figure 4. Indicators for assessing the level of development of circular processes in agriculture

Source: authors' development

circular transformations in the agricultural sector of Ukraine.

The agrarian circular economy system based on R-principles includes three main cycles: technical and technological, biological and financial. The basis of this model is the restorative closure of agricultural production cycles to address the pressing socio-economic and environmental problems of agricultural and rural development. The result of agro-cyclical transformations is an effective tool for achieving sustainable development goals in the agricultural and rural sectors.

According to the authors, the most promising areas for further development of Ukraine's agro-circular economy are the following:

- Promotion of organic production and use of its waste;
- reuse of wastewater from urban and rural areas and modernisation of agricultural irrigation methods;
- biomass use and bioenergy production;
- restoration of agricultural land;
- new marketing solutions for selling products and services of circular agricultural production.

Circular agriculture is a strategic priority for creating new closed cycles in agriculture. The creation of new fast process models should be based on the organisational, economic and technological combination of crop production, livestock production and the food industry. The result should be unified regional agri-food value chains based on resource recycling and minimising the consumption of new resources (crop residues, food, industrial processing of agricultural raw materials, manure, compost, etc.). The main tools of circular crop production should include precision agriculture, variable rate fertilisation, agroforestry, permaculture, digital soil moisture management, plant disease prevention and biological pest control. It is important to minimise the use of chemicals and increase the share of organic farming. Ukraine has a negative experience of rapid loss of black soil quality and deterioration of agricultural land. Restoration of land resources requires the use of organic materials and substances, the production of which can be ensured by creating closed agricultural cycles with the livestock industry and increasing the production and processing of organic raw materials.

Developing the circular potential of livestock production is another strategic priority for intensifying circular agricultural transformations. The key task is to reduce the duration of the cycle of substance circulation in feed production, minimise waste in the industry, and conserve energy and water resources. A prerequisite for creating closed livestock cycles is to strengthen integration with the crop and food industries to minimise the use of new feed inputs.

Both the agricultural sector and the national economy of Ukraine need to increase biogas

production. Under current and future conditions, this is the way to overcome Ukraine's energy dependence and differentiate its energy potential based on renewable energy sources. According to Ukrainian experts, the potential for biogas production is about 8 billion cubic metres annually. Such volumes would allow replacing almost half of the country's natural gas imports (Zhuk, 2022).

The solution to this problem is to create closed agricultural cycles of crop production, livestock and food industry. Feedstocks for biogas production can include livestock by-products (poultry manure, cattle and pig manure), corn silage, sugar beet pulp and food waste. Biogas production produces a valuable fermented product that can be used as a unique organic fertiliser that can replace chemicals and minimise the amount of new resources in agriculture. It also provides an appropriate impetus for the intensification of organic production.

Increasing biogas production as a priority strategic direction for the development of the agro-circular economy solves another important task of sustainable development of society – reducing greenhouse gas emissions and achieving the planned targets and commitments undertaken by Ukraine under the European Green Deal initiative.

The implementation of these areas has a strong potential for socio-economic benefits and bonuses for all participants. In order to ensure them, it is necessary to overcome the existing barriers in the near future, the main ones being the following: low level of motivation and understanding of the culture of agro-circular processes, imperfect regulatory and information support, lack of a clear mechanism for coordinating the development of the agro-circular economy at all levels of management, lack of financial resources of a significant number of agricultural companies in Ukraine, and the ongoing military conflict. Overcoming these challenges will help to actively create the preconditions for an inclusive and sustainable agricultural economy and ensure the country's food and national security.

5. Discussions

The authors of the article point out that the study collected and used certain limitations in the data information system. Dependence on agricultural production means that the amount and cost of newly attracted resources remains debatable. In particular, the level of material intensity of agricultural production depending on the size of agricultural units (large enterprises, medium-sized enterprises, small enterprises and farms) needs further research. The proposed system of indicators for assessing the level of cyclicity of agricultural processes requires an in-depth study in the scientific,

methodological and practical context in the context of combining agricultural and food industry enterprises into a single closed cycle. Under this combination of conditions, the methodological basis of the proposed indicators can be supplemented or partially changed.

One of the most controversial provisions of the implementation of circular economy principles in the practical sphere of the Ukrainian agricultural economy is the future potential of economic benefits for business. The studies conducted have shown the priority of attracting new types of resources for agricultural producers in Ukraine compared to their recycling and use. In addition, the linear way of organising economic relations and technological processes is traditional and economically acceptable for Ukrainian agribusiness. The use of chemicals and materials in agricultural production is also traditionally high. Abandoning them and switching to circular principles requires considerable effort, time, and significant investment from Ukrainian agricultural businesses. At the same time, one of the most controversial issues is the period and potential for future economic benefits for agricultural producers from the implementation of circular business models.

The rejection of short-term economic benefits (profits) in favour of a strategic perspective for Ukrainian farmers today seems too risky and unacceptable. Lüdeke-Freund et al. (2019) believe that the main types of future bonuses should be socio-economic impacts and effects from saving resources and preserving them for future generations. Boer et al. (2018) name the production of environmentally friendly and safe food among the main advantages of circular business models, Teigiserova et al. (2020) – reduction of waste. Rau et al. (2023), D'Amato et al. (2020), Helgason et al. (2021) consider the benefits of the circular economy as strategic solutions in terms of achieving sustainable development goals. The transparency of strategic vectors of development and economic recovery through digital transformation of processes is considered in the works of Irtyshcheva I. (2022), Kramarenko I. (2022), Pryshchepa O. (2020). While generally agreeing with these opinions, it is believed that at this stage of development of circular processes in Ukraine, their content is not entirely clear and accessible to most agricultural companies in Ukraine. One of the most controversial aspects of agro-circular business models is the timeframe for their implementation and the high level of economic efficiency in terms of capital investment. In this regard, for countries where the amount of state support for structural cyclical transformations is significantly limited (Ukraine), it is necessary to find bonuses of purely economic origin that would become drivers and incentives for the transition of

agricultural producers from a traditional to a closed development model. Among the possible instruments for creating such incentives, the authors see an increase in grant assistance from the European government and, possibly, providing Ukrainian farmers with access to long-term preferential loans. The authors believe that such instruments can be implemented in the presence of guarantees from the Ukrainian government and active information and analytical support for promoting transformations towards sustainable development of the agricultural sector and rural areas of Ukraine.

6. Conclusions

Studies have shown that there is an urgent need to develop circular processes in agriculture. Increasing the level of circularity contributes to achieving sustainable development goals and solving the global problem of food security. The agricultural sector is characterised by significant differences from other types of economic activity, primarily by the use of natural and biological resources and a significant impact on the environment and wildlife. Despite the active green economy policy adopted by the EU and Ukraine, the pace of intensification of circular transformations in agriculture remains slow. Existing models of the agro-circular economy are complex in terms of their organisational and economic support and practical implementation. In addition, the methodological framework for assessing the level of cyclicity of agricultural processes and their efficiency still needs to be developed. Agriculture is the main sector of the national economy of Ukraine. Throughout the duration of the military conflict, it has demonstrated stability and positive financial performance. The development of agriculture in Ukraine is intensive and largely focused on the use of traditional linear approaches to the organisation of agricultural production processes.

A comparison of the use of chemicals in agriculture in the EU and Ukraine has shown that the use of mineral fertilisers and pesticides in Ukraine is significantly higher than in other European countries. The deterioration of land quality and high rates of biodiversity loss have been a significant problem for Ukraine's agricultural sector for many years. Despite rising environmental costs in the agricultural sector, the share of agriculture in waste generation is increasing and carbon dioxide emissions are rising. At the same time, the percentage of ploughed farmland in Ukraine is the highest in Europe (81%), and the area treated with pesticides is over 91%. These results indicate the extreme urgency of the transition of Ukrainian agriculture to an agro-circular model of further development. The main reasons for the slow pace of agro-circular transformation were

identified as: a low culture of perception of sustainable development goals and circularity among small and medium-sized businesses, lack of appropriate infrastructure, and lack of financial resources among farmers. The analysis showed a high degree of dependence of the modern linear form of agricultural organisation in Ukraine on the costs of new production resources.

To improve the methodological framework for monitoring and evaluating the level of agricultural circularity in Ukraine, an attempt was made to

present a system of indicators along five main dimensions. The study substantiates the critical priority areas for further development of circular processes in the agricultural sector of Ukraine, including: circular agriculture, reduction of the cycle of substances in feed production, integration of crop, livestock and food industries; increase in biogas production, further development of organic production. These areas should be implemented in the context of the Sustainable Development Goals of Ukraine and the EU.

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