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Circular economy of the agricultural sector: Strategies and challenges in the context of globalisation

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Abstract. The study aimed to validate the necessity of formulating and executing plans for incorporating the concepts of the circular economy into Ukraine's agriculture sector, while considering the impacts of globalisation and problems arising from the war. This study examined the fundamental principles and intellectual underpinnings that differentiate the circular economy from the conventional economic model. The

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fundamental concept of the circular economy in the agricultural sector was justified, and the primary benefits of implementing this economic model in the field of agriculture were established. The European Commission has approved the strategy for the Common Agricultural Policy for the period 2023-2027. This strategy emphasises the primary responsibilities that EU member states must undertake to implement the principles of the circular economy in agriculture. The primary patterns in the operation of agriculture in Ukraine are recognised, and the significance of the agricultural sector in the framework of gross domestic product (GDP) formation and foreign exchange profits is established. The destruction of infrastructure, mining activities, and occupation of regions resulted in a decline in the cultivated land and animals, leading to a loss in physical productivity. Due to the war, there has been a decline in production and logistics capabilities, resulting in a large fall in the export of agricultural products. Consequently, the profitability of firms in this sector of the Ukrainian economy has also decreased. Ukrainian agricultural firms lack the financial resources to independently support creative development, which includes the implementation of new technology solutions that form the foundation of the circular economy. Considering the effects of globalisation and military conflict, it is justified that prioritising innovation and investment support, particularly by the State, should be a strategic direction for implementing the principles of the circular economy of agriculture in Ukraine. This approach will enhance economic efficiency and create new opportunities

Keywords: agriculture; closed-loop model; sustainable development; waste recycling; regenerative agriculture; biotechnology

INTRODUCTION

The linear economy, characterized by 'production-consumption-disposal,' is declining due to its role in depleting natural resources, polluting ecosystems, and driving climate change. This has increased the need for alternative models that promote sustainable development and resource conservation. The circular economy offers a solution, combining economic benefits with environmental protection by conserving resources, reducing waste, and utilizing renewables (Kirchherr *et al.,* 2023). Unlike the linear model, it creates closed cycles where materials and products are reused, and waste is converted into resources for future production. Implementing a circular economy in agriculture can mitigate environmental impacts, boost economic productivity, and achieve social balance. This is particularly relevant for Ukraine, where agriculture is crucial to the economy, contributing significantly to GDP, job creation, export earnings, and financial stability, especially after the damage to the metallurgical industry from Russian aggression. Despite global challenges, the circular economy's potential in Ukraine's agricultural sector is immense and could be vital for the country's sustainable economic development.

The circular or closed-loop economy is one such model that is increasingly attracting the attention of scientists in the modern world of the global economy. O. Dovgal *et al.* (2024) studied this topic in the context of Ukrainian realities. The authors' conclusion states that, despite the challenging circumstances, Ukraine is making progress in implementing the principles of circular economy and sustainable development, albeit it is not fully implemented. State-level entities are currently establishing distinct structures and implementing corresponding regulations, which has garnered a favourable response from businesses. The authors highlight that Ukraine has the potential to emerge as a frontrunner in adopting the concepts of the circular economy, especially following its recovery from the devastating aftermath of the conflict. In essence, everything will be completely recreated, giving us a competitive edge over other countries that have to reconstruct their current manufacturing, logistics, and infrastructure capacities in order to follow circular economy ideas.

Problematic aspects of the functioning of the Ukrainian agro-industrial complex have been studied by O. Shebanina *et al.* (2023). The papers note the need to develop mechanisms to stimulate partnerships based on private investment in waste management, encourage the use of recycled materials and support the introduction of innovative technological solutions. Some researchers conclude that the strategic directions for further progress of Ukraine's economy in the coming years, in the face of global challenges, are the rational use of available resources and the modernization of existing production facilities, which will enable economic recovery (Shubalyi *et al.*, 2023). In the context of the agricultural sector, researchers note that most agricultural enterprises use outdated equipment, which negatively affects productivity and product quality. Often, agricultural enterprises have a low level of management culture and organizational structure, which leads to inefficient use of resources and low labour productivity. The military invasion of Ukraine has significantly exacerbated existing challenges and created new problems for the agricultural sector of the national economy.

Although there have been scientific advancements, the implementation of circular economy principles and methodologies in the Ukrainian agricultural sector remains inadequately researched. This is particularly pertinent in the present circumstances marked by global

concerns and issues linked to the military war in Ukraine. The purpose of the study is to provide evidence for the necessity of developing and implementing strategies to use circular economy principles in the agricultural sector of Ukraine. To achieve this objective, it is imperative to examine the fundamental principles of the circular economy, its benefits and drawbacks for the agricultural industry, and the viability of introducing this model in the present circumstances of Ukrainian agriculture through innovative approaches. The reason for this is that innovation and technology play a vital role in the shift towards a circular management model. This model necessitates a comprehensive approach to creating suitable policies and assuring their support and implementation by government, academia, and business.

MATERIALS AND METHODS

The study applies the method of extrapolation to extend the findings on the circular economy to the agricultural sector, identify its main principles and highlight its economic benefits, in particular in agriculture. The analysis of the European Commission's Common Agricultural Policy (CAP) for 2023-2027, which is part of the EU's Green Deal (Delivering the European..., 2021), provides a framework that Ukraine can follow to implement circular economy principles in agriculture. The essay uses data from the State Statistics Service of Ukraine to highlight the importance of agriculture to the Ukrainian economy and the need for circular economy practices. In particular, it looks at the GDP and monetary value of agriculture, forestry and fisheries (State Statistics Service, n.d.). Using dynamic analysis and the calculation of averages, the average growth rates of GDP and the agricultural sector from 2013 to 2023 were determined and estimated. The article also calculates the share of agriculture in GDP from 2013 to 2023, distinguishing between the pre-war (2013-2021) and the war (2022-2023) periods to identify relevant trends.

To evaluate the effects of the conflict and determine the current patterns in Ukraine's agricultural industry, we analysed the growth rates of cultivated land for specific crops and the animal population using official information from 2021 to 2023 (State Statistics Service, n.d.). To assess the impact of changes in the volume of sown areas and the number of livestock on the performance of the country's agriculture, the agricultural production index was used, which is one of the key economic indicators used to study changes in agricultural production over a certain period. This index reflects not only the total volume of production, but also allows analysing the structure and dynamics of changes in different segments of the agricultural sector.

Using structural analysis, the share of agricultural products in the total structure of exports was calculated based on statistics on export operations in foreign economic activity and the dynamics of this indicator was presented (State Statistics Service, n.d.). The analysis was carried out for the period from 2018 to 2023 in the context of individual export items of crop and livestock products. Based on an analysis of the shares of loss-making and profitable enterprises in agriculture for the period 2021-2023, and using statistics on expenditures on basic, applied research and scientific and technical (experimental) development in agriculture, forestry, and fisheries (official data available for the period 2021-2022), the main challenges and problems that hinder the implementation of the principles of the circular economy in the country's agricultural sector were identified and substantiated (State Statistics Service, n.d.).

RESULTS

The circular economy aims to optimize resource efficiency and minimize waste, contrasting with the linear economy's "extract, manufacture, consume, and dispose" model. It promotes closed-loop systems where resources are recycled and reused (Corvellec *et al.,* 2022). Key principles include designing durable products that are easy to repair and upgrade, reducing the need for replacements and conserving resources. The product-as-a-service model, where items are leased or rented, encourages manufacturers to produce high-quality, long-lasting goods since they retain ownership and responsibility for maintenance and disposal (Marsh *et al.,* 2022). Another principle is utilizing production waste as a resource, integrating materials traditionally discarded back into production through recycling, composting, or repurposing (Kennedy & Linnenluecke, 2022). The circular economy also emphasizes the regenerative use of resources, such as using renewable energy, restoring ecosystems, and ensuring sustainable resource extraction. Applied to agriculture, these principles support sustainable development, food security, resource efficiency, and waste reduction (Fassio & Chirilli, 2023).

Several crucial issues should be encompassed while implementing the core concepts of the circular economy in the agricultural sector. These include utilising agricultural waste in production processes, such as converting crop residues into biogas or compost. Additionally, it involves using natural and biodegradable materials for packaging and storing products, adopting drip irrigation systems and reusing water for irrigation purposes. Furthermore, it entails promoting organic farming practices, minimising the use of pesticides and chemical fertilisers, supporting biodiversity, and implementing recycling and reuse strategies for waste, whether it be for creating new products, animal feed, or fertiliser (Yang *et al.,* 2023). The application of circular economy principles in the agricultural sector has several advantages, such as a decreased environmental impact. This is achieved by minimising waste and reducing the utilisation of chemicals, which in turn helps to protect ecosystems and enhance the quality of soil and water resources (Selvan *et al.,* 2023). The aforementioned factors contribute to the preservation

of crop productivity and the mitigation of risks related to severe weather conditions. This leads to improved economic efficiency by promoting the judicious utilisation of resources and the recycling of waste, resulting in reduced production expenses and enhanced profitability for agricultural enterprises (Kucher *et al.,* 2021).

The European Green Deal advocates for the implementation of a circular economy framework, which seeks to minimise waste and optimise the utilisation of resources (Arru *et al.,* 2022). This entails the reconfiguration of products, processes, and business models with the aim of diminishing resource use and enhancing recycling and reuse. The Circular Economy Action Plan delineates strategies to accomplish this objective, encompassing more stringent rules on single-use plastics and incentives for sustainable product design (Chioatto & Sospiro, 2023). In accordance with the aforementioned path, the European Union introduced the Common Agricultural Policy for the period of 2023-2027 in the year 2023. This policy initiative is crucial for the advancement of agriculture and rural areas in the EU. Its objective is to address pressing issues such as climate change, biodiversity decline, rural population decline, and unstable agricultural markets (Table 1).

***Table 1**. Main goals and objectives of CAP 2023-2027 in terms of applying the principles of the circular economy*

CAP 2023-2027 objectives	CAP 2023-2027 objectives in the context of ensuring the functioning of the circular economy of the EU agricultural sector
1. Increasing environmental sustainability and addressing climate change	1.Reducing greenhouse gas emissions: encouraging the use of emission-reducing practices in agriculture, such as precision agriculture and sustainable livestock management.
	2.Promoting biodiversity: support for measures that enhance biodiversity, including the conservation of natural habitats and the development of agroforestry.
	3.Sustainable resource management: efficient use of natural resources with a focus on soil health, water management and reduction of chemicals such as pesticides and fertilizers.
	4. Measures to promote circular practices, such as organic farming, agroecology and the use of biogas from agricultural waste.
2.Strengthening the socio-economic structure of rural areas	To promote economic growth, job creation, women's involvement in agriculture, social integration and regional development of rural areas, as well as the development of a circular bioeconomy and sustainable forest management.
3. Promoting knowledge and innovation	Knowledge sharing and training: facilitating access to knowledge and best practices through training programmes, advisory services and farmer networks.
	Research and development: supporting agricultural research to develop innovative solutions for sustainable agriculture.

***Source:** compiled by the authors based on The common agricultural policy: 2023-27 (2023)*

The Common Agricultural Policy for the period 2023-2027 is a component of the Farm to Fork strategy. The strategic initiative, initiated in 2020, delineates multiple objectives that align with the concepts of the circular economy. The primary objective is to minimise food waste. The objective of the strategy is to minimise food waste per person by 50% at the retail and consumer stages by 2030, while also decreasing food losses across the entire manufacturing and consumption process. Furthermore, it promotes the use of farming techniques such as precision agriculture, agroecology, organic farming, and agroforestry. These methods enhance soil health and biodiversity while minimising the reliance on pesticides (Dey *et a*l., 2022). Furthermore, the plan entails enhancing resource utilisation efficiency, specifically with regards to water and soil, by implementing techniques such as crop rotation, cover crops, and conservation agriculture (Moreira *et al*., 2023). Lastly, it aims to minimise the use of chemicals, specifically by decreasing reliance on chemical pesticides and fertilisers through the promotion of integrated pest management and organic farming methods that safeguard ecosystems and human well-being. Hence, the incorporation of circular economy principles into agriculture holds significance for EU nations, as seen by the Farm to Fork strategy (n.d.) and the European Green Deal. The agriculture industry in Europe may make a substantial contribution to a sustainable and resilient food system by minimising waste, preserving resources, and advocating for circular economy principles. Agriculture plays a crucial role in Ukraine's food security and overall economy. The significance of this sector has notably grown in recent years, particularly during the war (Table 2).

***Table 2**. Comparison of Ukraine's GDP and the share of the agricultural sector in the GDP structure in 2013-2023*

Years	GDP, nominal, UAH million	Agriculture, forestry and fisheries, UAH million
2013	1,465,198	128,738
2014	1,586,915	161,145
2015	1,988,544	239,806

Table 2. Continued

Years	GDP, nominal, UAH million	Agriculture, forestry and fisheries, UAH million
2016	2,385,367	279,701
2017	2,981,227	303,419
2018	3,560,302	360,998
2019	3,977,198	356,563
2020	4,222,026	393,077
2021	5,450,849	593,367
2022	5,191,028	444,024
2023	6,537,825	484,150

Source: *compiled by the authors based on the State Statistics Service of Ukraine (n.d.)*

During the study period, the agriculture sector's contribution to the GDP structure grew about ten times. At the same time, if we compare the data before the military year of 2021 with 2013, the growth was almost 4.61 times, which outpaced the growth of GDP itself, which in 2021 grew by only 3.7 times compared to 2013. This is evidence that agriculture grew faster than any other sector of the country's economy. The share of agriculture in the GDP structure of Ukraine in the period 2013-2023 was constantly fluctuating, and averaged about 10% in the pre-war period (until 2022) (Fig. 1).

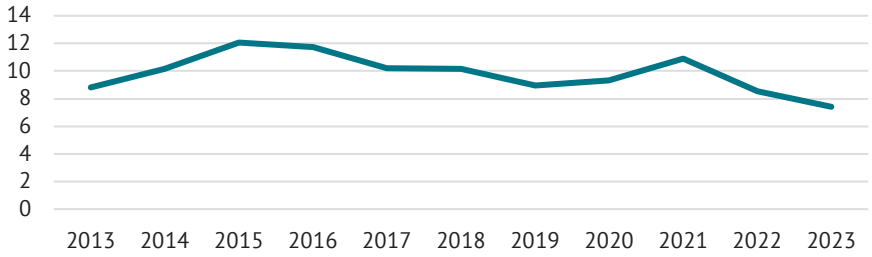

Figure 1*. The percentage contribution of the agricultural industry to the structure of GDP from 2013 to 2023*
Source: *compiled by the author based on the State Statistics Service of Ukraine (n.d.)*

However, as a result of the war, the share of agriculture in the country's total GDP decreased by 2.33% in 2022 and by another 1.15% in 2023. The war has intensified numerous destructive processes that have had a negative impact on Ukraine's agricultural sector. The hostilities resulted in the destruction, contamination, or seizure of large areas of agricultural land (Table 3).

Table 3*. Percentage change in the area under crops in Ukraine*

Years	Cereals and pulses	Beetroot	Sunflower	Potatoes	Vegetable crops
2021/2022	-23.91	-18.94	-20.07	-5.85	-17.83
2022/2023	-9.74	35.87	-1.38	0.17	5.03

Source: *compiled by the author based on the State Statistics Service of Ukraine (n.d.)*

In general, over the two years of war, the area under grain decreased by 33.65%, sunflower by 21.45%, potatoes by 5.68%, vegetables by 12.8%, with only beetroot showing positive dynamics and increasing by 16.93%. In the frontline regions and regions where hostilities are ongoing, in particular in Zaporizhzhia, Kharkiv, Donetsk and Kherson, a significant part of the land used for growing grain crops became unsuitable for cultivation due to hostilities and mining. Restoring and expanding cultivated areas in safer regions, such as Poltava and Vinnytsia, has become a priority to maintain food security. Zaporizhzhia and Kherson regions, which have traditionally been leaders in sunflower cultivation, also experienced a significant reduction in acreage. Dnipro and Kropyvnytskyi oblasts remain important regions for sunflower cultivation, although they also face certain difficulties due to logistical and economic issues. In addition, landmines, infrastructure destruction, and the destruction of machinery and storage facilities have reduced the ability to cultivate fields and store products. Some regions that used to be key to agricultural production have become inaccessible or unsafe for farming. The same negative trends exist in livestock production, as evidenced by the number of farm animals (Table 4).

***Table 4**. Volumes of farm animals in Ukraine for the period 2021-2024 (data as of 1 January of the respective year)*

Years	Number of farm animals (thousand heads)			Poultry, million heads
	Cattle	Pigs	Sheep and goats	
2021	2,874	5,876.2	1,140.4	200.7
2022	2,644	5,608.8	1,094.3	202.2
2023	2,307.1	4,948.3	941.4	180.5
2024	2,156.2	5094	906.3	184.7

***Source:** compiled by the author based on the State Statistics Service of Ukraine (n.d.)*

Some farms were caught up in the hostilities, which led to the loss of livestock, destruction of infrastructure and reduced production. It also made logistics and exports more difficult. The rising cost of feed, energy, and other production costs has put many farmers under pressure. Additional pressure on the industry was exerted by currency fluctuations, which affected production costs and competitiveness on foreign markets. As can be seen from the table, during the study period, there was a negative trend in the number of almost all types of livestock in Ukraine (Fig. 2).

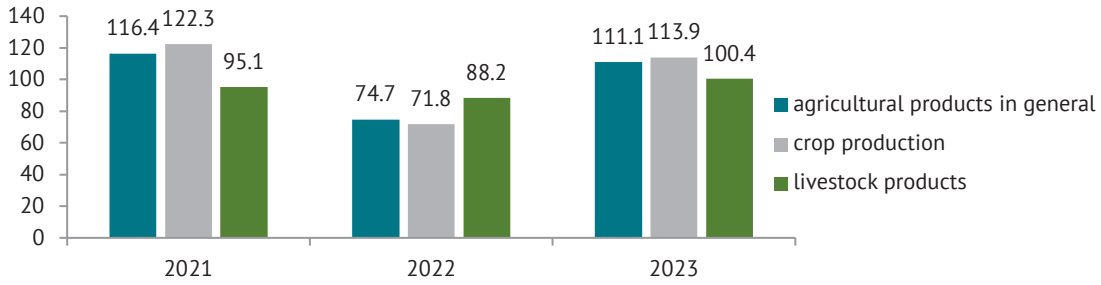

***Figure 2**. Indices of agricultural products in Ukraine for 2021-2023*
***Source:** compiled by the author based on the State Statistics Service of Ukraine (n.d.)*

Despite a slight increase in agricultural production indices in 2023, against the backdrop of a drop in 2022 due to military operations in Ukraine, agricultural production volumes have not yet reached the levels of 2021. Thus, the average value of production volumes in various agricultural sectors (crop and livestock) in 2023 was 14.2% lower than in pre-war 2021. It should also be noted that the decline in physical output in 2022 was more pronounced in the crop sector, with specialized enterprises showing a more rapid decline. For example, the output of agricultural enterprises decreased by almost 30%, while the decline in production by households was about 20% (State Statistics Service, n.d.). The war has also led not only to a reduction in production capacity, but also to more complicated logistics and the loss of markets. Blocked ports, destroyed roads and railways, and the imposition of export restrictions due to the hostilities have made it much more difficult or even impossible to deliver products to end consumers. This has led to a decline in farmers' incomes, affected GDP, and consequently affected exports and foreign exchange earnings, which are essential for stabilizing the hryvnia in the foreign exchange market. In recent years, the agricultural sector has become the flagship export sector of the Ukrainian economy (Table 5).

***Table 5**. Share of exports of selected agricultural products in 2018-2023*

Export items, %	2018	2019	2020	2021	2022	2023
Live animals, products of animal origin	2.6	2.6	2.4	2	3.3	3.8
Products of plant origin	20.9	25.8	24.2	22.8	30.5	32.4
Including cereals	15.3	19.2	19.1	18.1	20.6	23
Fats and oils of animal or vegetable origin	9.5	9.5	11.7	10.3	13.5	15.6

***Source:** compiled by the author based on the State Statistics Service of Ukraine (n.d.)*

The most significant export item in the agricultural sector is the sale of grain crops, with its share increasing by almost 8 percentage points in 2023 compared to 2018. In general, the agricultural sector has become the dominant sector in the structure of exports of foreign economic activity of business

entities during the period under review. While in 2018 the share of agriculture was 33%, in 2023 it was 52%. However, the volume of export earnings for all agricultural products has significantly decreased over the 2 years of war, and for some items still does not reach the level of 2019 (Fig. 3).

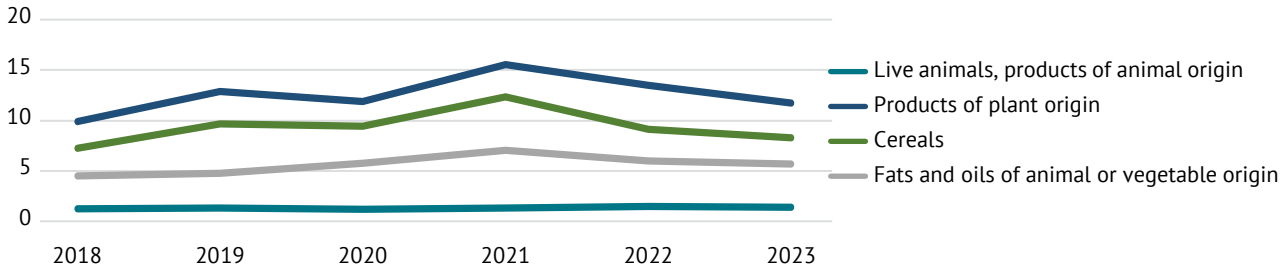

***Figure 3**. Dynamics of export revenue from agricultural products, billion USD (for the period 2018-2023)*
***Source:** compiled by the author based on the State Statistics Service of Ukraine (n.d.)*

As can be seen from the figure, the most rapid decline in export earnings is observed for plant products, of which cereals are a component. The total decrease in foreign exchange earnings from grain exports in 2022-2023, compared to the pre-war year 2021, was almost 33%. All of the above necessitates the formation of a strategy for the implementation of an intensive type of agricultural sector development based on the circular economy as a promising area that combines economic efficiency and environmental sustainability (Silvius *et al.*, 2023). The introduction of innovative technologies and the transition to closed production and consumption cycles not only increase productivity without expanding production capacity or increasing sown areas, which is especially significant for Ukraine, but also create a more sustainable agricultural system capable of coping with the challenges of the modern world (Vinayagam *et al.*, 2023).

In order to make progress in sustainable production and consumption, innovation plays a vital role (Gonçalves *et al.,* 2022). In the field of agriculture, where the availability of natural resources is crucial, the adoption of innovative practices is necessary in order to shift towards a circular economy (Rusch *et al.*, 2023). Technological advancements, such as the utilisation of drones and sensors in precision farming, improve resource management by optimising the allocation of water, fertiliser, and pesticides (Yrjälä *et al.,* 2022). This method decreases expenses and minimises the ecological footprint. Furthermore, contemporary biotechnologies facilitate the transformation of agricultural waste into useful commodities such as biochar, biogas, and organic fertilisers, hence diminishing waste and dependence on non-renewable energy sources (Sant'Ana *et al.*, 2024). The 2023 strategy for the development of Ukraine's agro-industrial complex emphasises the importance of recycling and biomethane production as major components of the circular economy (Ministry of Agrarian Policy and Food of Ukraine, 2023).

Novel agricultural solutions are progressing the utilisation of alternative raw resources, such as insect proteins and algae, for the production of biofuels (Rauw *et al.*, 2023). These alternatives alleviate the burden on conventional systems and promote sustainable development, which is a fundamental principle of the circular economy. In addition, the implementation of innovative packaging technologies such as biodegradable materials and smart packaging has shown effective in prolonging the shelf life of food products and minimising food waste (Kusumowardani *et al.,* 2022). This, in turn, contributes to the resolution of global hunger and food security concerns (Muscio & Sisto, 2020). Utilising digitalisation and information sharing platforms is essential for implementing circular economy concepts, as they facilitate effective and sustainable farm management (Kleisiari *et al.,* 2021; Ye *et al.,* 2023). Shared agricultural machinery platforms help small farms avoid resource overproduction and lower capital costs. This results in a reduction in the release of greenhouse gases and the consumption of resources, as evidenced by research undertaken by C. Lehmann *et al.* (2022). Investments are essential for fostering innovation and economic growth as they offer financial backing for research and development. This, in turn, leads to the development of innovative solutions and enhances the competitiveness of industries (Bjerke & Johansson, 2022).

Companies and private investors also play a major part in funding research (Zou & Li, 2022). This can be beneficial for businesses, as innovation and new technologies can lead to competitive advantages. Famous examples include investments by large corporations in research in IT, pharmaceuticals, and biotechnology. Investments also contribute to the creation and development of the necessary infrastructure for innovation in all areas, including the agricultural sector. This includes both physical infrastructure (e.g. laboratories, production facilities) and digital infrastructure (e.g. high-speed internet, cloud technologies). A well-developed infrastructure can accelerate the process of developing and adopting new technologies in business (Baah *et al.*, 2024). In addition, investments in education, training, and skills development contribute to the

creation of a strong human capital base ready to perform innovative tasks (Castillo-Valero & García-Cortijo, 2021). Investment in innovation can also be stimulated through government support and policies. Public investment in research, tax incentives for companies engaged in innovation, grants, and subsidies create favourable conditions for the development of innovation (Alston & Pardey, 2021).

Public policies aimed at supporting innovation help to attract private investment in this area (Wang *et al.*, 2021). This is relevant for Ukrainian agricultural companies, as it is quite difficult to finance innovative developments in the current environment, as enterprises have significantly reduced production and sales volumes, which significantly affects their profitability (Fig. 4).

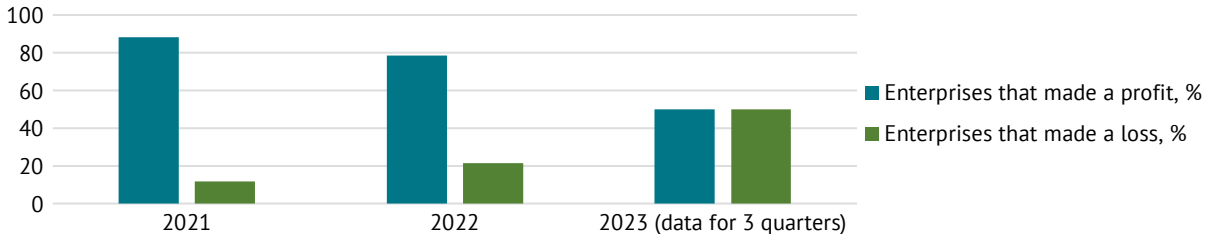

Figure 4. *Structure of profitable and unprofitable enterprises in agriculture in 2021-2023*
Source: *compiled by the author based on the State Statistics Service of Ukraine (n.d.)*

As the figure shows, the situation with regard to profitability for Ukrainian agricultural enterprises has deteriorated significantly: while in 2022 only a fifth of enterprises was unprofitable, in 2023 (data for the first 9 months of the year are available) this figure increased by almost 30 percentage points, meaning that half of all agricultural enterprises made losses. This state of affairs leads to their inability to finance innovations at their own expense, which is also evidenced by the statistics of low innovation and investment activity in the activities of agricultural enterprises (Fig. 5).

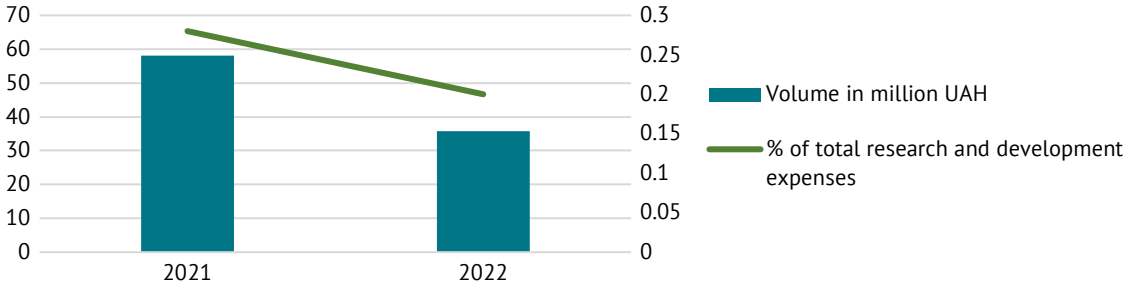

Figure 5. *Expenditures on basic and applied research and scientific and technical research (developments in agriculture, forestry, and fisheries)*
Source: *compiled by the author based on the State Statistics Service of Ukraine (n.d.)*

The data shows a decline in agricultural research and development (R&D) spending and its share of the total R&D budget in Ukraine. The restricted allocation of finances for agricultural innovation is primarily driven by economic volatility, including fluctuations in currency, high inflation rates, and economic downturns. These factors discourage the long-term commitment of resources. Small and medium-sized agricultural firms encounter substantial obstacles in accessing cost-effective financing as a result of elevated expenses and limitations. Although there have been some improvements through state concessional lending, these efforts have been further hindered by the ongoing war. In addition, the war has exacerbated the movement of young people from rural areas, which in turn diminishes the number of specialists available to drive innovation. The industry is confronted with difficulties stemming from a dearth of specialised education, obsolete technologies, and insufficient infrastructure. The lack of access to technology, information, and platforms for exchanging knowledge significantly impedes innovation in agriculture.

In addition, an unstable legal framework and frequent regulatory changes create uncertainty for investors. An imperfect system of property rights protection and bureaucratic obstacles also reduce the attractiveness of investment in the sector. High levels of corruption in government agencies involved in agricultural regulation discourage investment. Investors often face non-transparent procedures and demands for bribes. In general, support from government and international institutions is needed to successfully implement innovations in the agricultural sector and ensure the principles

of a circular economy. This could include subsidies for research and development, creating favourable conditions for investment in environmentally friendly technologies, and promoting cooperation between science and business. However, this should be done on the basis of a specific strategy with goals, objectives, and indicators.

DISCUSSION

The study's findings highlight the circular economy as a groundbreaking approach to addressing urgent environmental and economic challenges. The circular economy promotes a closed-loop system that prioritises the reuse, repair, refurbishing, and recycling of resources, in contrast to the traditional linear economy's "take, make, dispose" strategy. E. Arruda *et al.* (2021) similarly identify the circular economy as a shift towards sustainable development amid global challenges. While A. Velenturf and P. Purnell (2021) emphasize circular economy concepts, this research stresses the importance of implementing these principles to address resource depletion and scarcity. The circular economy fosters innovation, economic growth, and environmental benefits, aligning with V. Shebanin *et al.* (2022) on sustainable development through closed-loop technologies. J. Velasco-Muñoz *et al.* (2021) note that agriculture faces resource depletion, climate change, and pollution, requiring new technical solutions, with Q. Ren and J. Albrecht (2023) advocating for circular economy strategies in agriculture to address these issues.

Primarily, these are ecological advantages. The agricultural industry is a substantial contributor to the release of greenhouse gases, the contamination of water, and the deterioration of soil quality. The adoption of a circular model effectively minimises the environmental impact by optimising resource utilisation. For instance, instead of incinerating or depositing crop residues in landfills, they can be utilised as organic fertiliser. This practice reduces the reliance on chemical fertilisers and enhances soil structure, as highlighted by M. Martínez-Moreno *et al.* (2024) in their examination of current circular economy practices, obstacles, and motivators in the agricultural sector.

The method, as advocated by A. Khajuria *et al.* (2022), is crucial for establishing a sustainable food system and enhancing environmental resilience. Strategies encompass regenerative agriculture, utilisation of renewable energy, recycling of trash, and implementation of closed production cycles. Regenerative approaches, such as low tillage and crop rotation, help restore ecosystems. Innovations like vertical farming improve resource efficiency, especially in locations with limited water availability (Shah *et al.,* 2024). Renewable energy sources such as solar and biogas diminish dependence on fossil fuels and enhance waste management efficiency (Shahini *et al.,* 2023). Ukraine is confronted with a notable obstacle due to the lack of a comprehensive state strategy for agricultural development based on circular economy concepts. Ukraine should utilise its abundant natural resources and important economic position to promote a circular agricultural sector. This is essential for achieving economic growth, ensuring food security, and maintaining sustainability.

In general, agriculture, excluding the processing component, accounted for more than 10 percent of GDP between 2013 and 2021, while during the war years this figure fell to about eight percent. However, despite this, agriculture remains the main export item of the national economy, accounting for more than 50 per cent of all export transactions. However, according to the study, the amount of foreign exchange earnings has significantly decreased compared to 2021. All this happened as a result of the war, which, along with existing problems for the agricultural sector, such as the lack of state support and regulatory mechanisms, high costs of introducing new technologies and innovations, which is a significant obstacle for many farms that cannot afford the transition to a circular model of management, limited information and relevant education, has caused new challenges for Ukrainian agriculture. First and foremost, it is the destruction of infrastructure, as the hostilities have led to the destruction of farms, transport, and logistics facilities (Dunayev *et al.*, 2024). The absence of adequate infrastructure poses challenges to the implementation of circular economy ideas. Infrastructure has a crucial role in aiding the transition to a circular economy, especially in the agricultural sector (Nunes & Sytnychenko, 2024). The circular system necessitates the presence of physical assets and services for the collection, transportation, processing, storage, and distribution of resources. This requirement is supported by the findings of the conducted study, as well as the results of the study done by A. Nogueira *et al.* (2020).

Another significant problem today is landmines and the "contamination" of agricultural land with unexploded ordnance, which makes it impossible to use it safely. The armed conflict has also led to the migration of people, particularly agricultural workers in the south-east of Ukraine, which has led to labour shortages in many sectors of the agricultural sector. This makes harvesting, animal care and other important agricultural tasks difficult. In addition, it leads to the loss of knowledge and experience that has been accumulated over generations and makes it difficult to introduce new technologies and practices, as well as to lower productivity and product quality, as also pointed out by N. Musayeva *et al.* (2024), who study the role of innovation in mitigating the effects of war on Ukrainian agriculture. All of the above has had a significant negative impact on the Ukrainian agricultural sector, which is confirmed by the data obtained in this study. In particular, there was a significant decrease in the area under crops, almost all major crops, and a decrease in livestock. As a result, the physical volume of production decreased significantly, which, combined with the logistical difficulties

of selling it both domestically and abroad, led to the loss of national agricultural enterprises. In particular, in 3 quarters of 2023, half of all agricultural enterprises made losses. Accordingly, this makes it impossible to carry out innovative activities, which cannot be fully implemented without investment support.

The utilisation of new technology in contemporary agricultural practices is being propelled by globalisation processes. This is primarily aimed at enhancing crop yields, optimising resource utilisation, and mitigating environmental consequences. These efforts align with the core principles of the circular economy (Reshetilov, 2022). Investing in research and using cutting-edge technologies are crucial for the advancement of circular models in the agricultural industry. This encompasses the advancement of novel processing techniques, biotechnology, and management information systems. The circular economy promotes the advancement of novel technologies and strategies that can enhance the sustainability and productivity of the agricultural sector, as supported by the research conducted by D. Pemsl *et al.* (2022). For instance, precision farming technologies have the ability to optimise the use of water and fertilisers, resulting in a reduction in their consumption and an increase in crop yields. Biotechnology enables the development of novel crop varieties that possess resistance against pests and diseases, hence diminishing the reliance on pesticides.

Globalisation and wartime challenges necessitate that the agricultural sector adopts modern technologies and innovations to meet increasing demands, adapt to climate change, and stay competitive globally. These changes enhance productivity, sustainability, and food security. Strategic international cooperation, infrastructure development, technological advancements, and skilled workforce training are crucial for integrating agriculture into the global economy. Securing investments and support from government and international organizations will help Ukraine's agricultural sector grow, particularly through adopting a circular economy approach. This involves funding R&D for new technologies, supporting small businesses in circular economy practices, and providing education for farmers on these new methods.

CONCLUSIONS

The proportion of agriculture in the composition of the Gross Domestic Product (GDP) varies approximately at a level of 10%. From 2013 to 2021, this industry experienced a higher growth rate compared to Ukraine's GDP. Additionally, when considering other industries like food processing and related processing, this figure might be substantially higher. Furthermore, Ukraine holds a prominent position as a major global exporter of agricultural products. Agricultural product exports contribute to over 50% of the nation's overall export revenue. However, the war has exacerbated the existing problems of the national agricultural sector and significantly reduced the production capacity of business entities due to the destruction of fixed assets, transport and logistics infrastructure, and a reduction in sown areas due to mining and seizure of territories. As a result, the volume of physical production in the sector has significantly decreased. This had a corresponding impact on sales opportunities, so foreign exchange earnings from agricultural exports decreased by 33% in 2022-2023. Farmers suffered significant losses, which also affected tax revenues to the state budget. The financial situation of agricultural enterprises does not allow them to invest in innovative development using their own resources, which is the basis for the introduction of modern technological solutions that ensure the formation of a circular economy in this area. Expenditures on research and development in agriculture in the period under review did not exceed 0.3% of the total expenditures for this purpose in all sectors of the economy. However, it should be noted that such conclusions are based on the available general statistics and do not take into account the innovation and investment activity of individual enterprises in the agricultural sector.

The conflict and economic volatility have diminished investor enthusiasm for Ukraine's agriculture industry. This has hindered the process of attracting investment in the development of the sector and the modernisation of manufacturing. The study highlights that investments in innovation and technology play a crucial role in implementing the principles of the circular economy, particularly in the era of globalisation. These investments enhance economic efficiency and generate new growth opportunities through precision farming, biotechnology, closed-loop systems, while also reducing the environmental impact. Ukrainian agricultural firms lack the financial capacity to independently provide the necessary investment support for the successful application of these technologies. Hence, this component should serve as the foundation for the state's strategic growth of the agricultural sector.

Additional research should focus on formulating a plan to provide financial assistance for the implementation of new technologies and innovations. This plan should involve the establishment of specific financial tools, partnerships between the public and private sectors, educational and advisory initiatives, infrastructure improvement, and the engagement of international investors. This strategy will facilitate the incorporation of circular economy ideas into the operations of Ukrainian agricultural firms and bolster the sustainable growth of the country.

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CONFLICT OF INTEREST

None.

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Циркулярна економіка аграрного сектора: стратегії та виклики в умовах глобалізації

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Анотація. Дослідження мало на меті підтвердити необхідність розробки та реалізації планів впровадження концепції циркулярної економіки в аграрному секторі України, враховуючи вплив глобалізації та проблеми, що виникли внаслідок війни. У цьому дослідженні розглядалися фундаментальні принципи та інтелектуальні підвалини, які відрізняють циркулярну економіку від традиційної економічної моделі. Обґрунтовано фундаментальну концепцію циркулярної економіки в аграрному секторі та встановлено основні переваги впровадження цієї економічної моделі в сільському господарстві. Європейська Комісія затвердила стратегію Спільної аграрної політики на період 2023-2027 років. Ця стратегія наголошує на першочергових обов'язках, які країни-члени ЄС повинні взяти на себе для впровадження принципів циркулярної економіки в сільському господарстві. Визнано основні закономірності функціонування сільського господарства в Україні та встановлено значення аграрного сектору у формуванні валового внутрішнього продукту (ВВП) та валютних надходжень. Руйнування інфраструктури, видобуток корисних копалин та окупація регіонів призвели до скорочення посівних площ та поголів'я тварин, що спричинило втрату фізичної продуктивності. Через війну відбулося зниження виробничих і логістичних можливостей, що призвело до значного падіння експорту сільськогосподарської продукції. Як наслідок, прибутковість фірм у цьому секторі української економіки також знизилася. Українським аграрним компаніям бракує фінансових ресурсів, щоб самостійно підтримувати творчий розвиток, який включає впровадження нових технологічних рішень, що формують основу циркулярної економіки. Враховуючи наслідки глобалізації та військового конфлікту, обґрунтовано, що стратегічним напрямом впровадження принципів циркулярної економіки в сільському господарстві України має стати пріоритетність інноваційної та інвестиційної підтримки, зокрема з боку держави. Такий підхід сприятиме підвищенню економічної ефективності та створенню нових можливостей

Ключові слова: сільське господарство; модель замкнутого циклу; сталий розвиток; переробка відходів; регенеративне землеробство; біотехнології