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ANTI-CRISIS POTENTIAL OF THE CIRCULAR ECONOMY FOR AGRICULTURE OF UKRAINE

АНТИКРИЗОВИЙ ПОТЕНЦІАЛ ЦИРКУЛЯРНОЇ ЕКОНОМІКИ ДЛЯ СІЛЬСЬКОГО ГОСПОДАРСТВА УКРАЇНИ

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The relevance of the study lies in the need to transform Ukraine's agricultural sector in line with sustainable development principles and global environmental challenges. Rising agricultural waste, soil degradation, and market instability highlight the importance of circular approaches to minimize waste, optimize resources, and enhance economic resilience. The article aims to justify the transition from a linear to a circular economy to strengthen crisis adaptability. Key research methods include analysis, synthesis, graphical, and bibliographic techniques. The results reveal waste dynamics, critical intervention points, and global best practices (e.g., biogas, composting). Circular innovations reduce environmental risks and boost profitability. The study's practical value lies in justifying circular model benefits for Ukrainian agribusiness based on a comprehensive sector analysis.

Keywords: anti-crisis potential, circular economy, crisis management, agriculture, agricultural waste.

Актуальність теми дослідження полягає в необхідності трансформації аграрної галузі України відповідно до принципів сталого розвитку та глобальних екологічних викликів. Зростання обсягів агровідходів, втрата ґрунтової родючості, а також нестабільність зовнішніх ринків підкреслюють важливість впровадження циркулярних підходів, що дозволяють мінімізувати відходи, оптимізувати використання ресурсів і підвищити економічну стійкість агропідприємств. Основна мета статті полягає у теоретичному обґрунтуванні та практичній оцінці необхідності переходу аграрними підприємствами України від традиційної (лінійної) моделі економіки до циркулярної в контексті підвищення їхньої адаптивності до кризових явищ. Під час проведення наукового дослідження були використані наступні методи: аналізу та синтезу – для систематизації теоретичних підходів до циркулярної економіки та оцінки їхньої релевантності для агросектору; графічні методи – для наочного представлення динаміки утворення агровідходів, структури їхньої переробки та міжнародних порівнянь; бібліографічні методи – для аналізу сучасної наукової літератури, звітів міжнародних організацій та досвіду провідних аграрних країн у впровадженні циркулярних практик. Основні результати дослідження відображають динаміку змін частки агровідходів у загальній структурі утворених відходів, що дозволило виявити критичні точки для втручання та потенційні напрями оптимізації. Проведено глибокий аналіз ключових проблем, з якими стикаються сільськогосподарські підприємства під час впровадження циркулярних рішень.Практична цінність статті полягає в обґрунтуванні переваг циркулярної моделі економіки для аграрних підприємств України на основі комплексного аналізу ключових показників агросектору та стану переробної діяльності.

Ключові слова: антикризовий потенціал, циркулярна економіка, антикризове управління, сільське господарство, агровідходи.

Problem statement. In a world of rapid change, constant uncertainty and global challenges such as climate change, resource depletion and economic crises, Ukrainian agriculture faces some challenges. Traditional (linear) economic models, which are characterised by the following features: materials move in a straight line from extraction to production and then to landfill; profits depend on creating, selling and consuming as much output as possible; inefficient processes lead to excessive pollution and overuse of natural resources, are becoming inefficient in the

long run. This is especially true in an unstable economy and with growing pressure on natural resources.

As a result, declining soil fertility, irrational use of water resources, accumulation of agricultural waste and dependence on imported inputs pose additional threats to the sustainable development of agriculture. In this context, the circular economy is emerging as a promising model of crisis management: products and waste are collected for reuse or recycling, new products have a «green» design focused on durability and recyclability, renewable energy is used instead of limited resources, and new business models for sharing assets (leasing) replace the emphasis on product ownership. These practices reduce waste, optimise resources, and establish closed production cycles.

According to the European Parliament, the circular economy is «a model of production and consumption that involves sharing, renting, reusing, repairing, restoring and recycling existing materials and products for as long as possible. This extends the life cycle of products» [1].

In turn, the World Economic Forum defines the circular economy as «an industrial system that is regenerative or regenerative by design» [2].

However, despite the obvious advantages, the implementation of circular approaches in Ukrainian agriculture remains limited due to some barriers, ranging from lack of awareness and technological backwardness to institutional obstacles and lack of incentives for innovation.

The study's relevance is driven by the need to find effective strategies that will allow Ukrainian agricultural enterprises to adapt to current challenges but also to become more resilient, competitive, and able to recover from crises. Studying the anti-crisis potential of the circular economy in agriculture will allow us to investigate key issues and develop evidence-based recommendations for forming sustainable agricultural development policy, particularly in the context of Ukraine's integration into the European economic area.

Analysis of recent research and publications. The study of the theoretical and methodological component of the circular economy is the subject of scientific works by both foreign and Ukrainian scholars: Alan Murray, Keith Skene, Kathryn Haynes, Sylvie Geisendorf, Felicitas Pietrulla, V. Gurochkina, M. Budzynska, M. Nagara, D. Nechytailo, V. Artemov, L. Shymanovska-Dianich and others.

Thus, according to Artemov V. and others, the circular economy is «an innovative approach to resource consumption that is becoming increasingly relevant in the modern world, an alternative economic model based on the implementation of closed cycles in the processes of production, circulation and consumption» [3].

Lucas Betthysseus notes in his works that «the circular economy is an economic model that aims to use resources efficiently, minimise waste and keep products and materials in circulation as long as possible» [4].

As defined by UNIDO, «the circular economy is an alternative to the traditional linear economic model where resources are used as long as possible, maximum value is extracted from them, and waste is returned from the end of the supply chain to the beginning, giving used materials a new life» [5].

L. Shymanovska-Dianich describes the circular economy as «a regenerative basis where resources are constantly recycled and repurposed» [6].

Despite a significant body of research, it is important to continue studying the circular economy, especially in the context of crisis management and agricultural sustainability. Further research could focus on developing adaptive strategies for Ukrainian realities, assessing the cost-effectiveness of circular approaches, and analyzing best international practices to integrate them into national sustainable development policies. Such an approach would not only help mitigate the crisis but also create long-term competitive advantages for Ukraine's agricultural sector.

Identification of previously unresolved parts of the overall problem. An important issue remains the study of the impact of the circular economy on increasing the competitiveness and strengthening the anti-crisis component of agricultural enterprises. After all, despite the growing attention to the concept of the circular economy, its practical implementation in agriculture, in particular in the face of economic instability, has not been sufficiently studied.

Formulation of the objectives of the article (statement of the task). The study aims to identify and substantiate the anti-crisis potential of the circular economy for agriculture in Ukraine, as well as to develop recommendations for the implementation of circular approaches to increase the sustainability of the agricultural sector in the face of instability.

Summary of the main research material. Crises are an integral part of doing business, as

any economic activity takes place in a dynamic and unpredictable environment. The factors that cause crises can be both internal (ineffective management, financial problems, operational process failures) and external (economic recessions, political instability, natural disasters, changes in legislation).

It is important to realise that no sector of the economy is completely immune to crises, including the agricultural sector. Agriculture remains vulnerable to numerous risks caused by adverse weather events (droughts, frosts, floods), outbreaks of plant and animal diseases, fluctuations in commodity and input prices, and changes in the political or economic environment.

Modern trends in the development of competitive agriculture call for the transformation of the traditional linear economic model to the principles of the circular economy. As Fatima Haque notes in her works, «in the agricultural sector, cyclical processes can include the processing of organic waste into compost or biogas, the use of perennial crops, the integration of intercropping and the use of biological plant protection methods» [7]. It is also worth adding that the circular economy model also involves the introduction of resource-efficient technologies, waste minimisation, rational use of natural resources and closed production and consumption cycles, which contribute to the sustainability of the agricultural sector and its environmental balance.

In the context of global changes and growing challenges related to the exhaustion of natural resources, environmental degradation and climate change, the principles of circular economy in agriculture are becoming increasingly important. The transition to closed production cycles contributes to the rational use of resources, reduction of waste and increased environmental responsibility of the industry. According to the Sustainable Agriculture Network, «circular agriculture can contribute to a more resilient and sustainable food system» [8].

Given the growing demand for food and the need to improve the efficiency of agricultural production, not only the expansion of production capacity but also the optimisation of land use play a key role. The introduction of modern agricultural technologies, increased farming intensity and adaptation to climate change are becoming integral elements of a sustainable agricultural development strategy. This allows not only to increase production volumes but also to improve its environmental and economic efficiency.

To comprehensively analyse the current state of the agricultural sector in Ukraine, a study of key indicators of agricultural production was conducted, the results of which are shown in Figures 1–3.

As shown in Figure 1, there has been a gradual increase in the area under major crops between 2013 and 2021. This trend is driven by several factors, including the introduction of modern agricultural technologies, increased investment in the sector, optimisation of the crop structure and increased productivity of land use. In addition, favourable market conditions, adaptation of agricultural producers to climate change and government support for certain segments of agricultural production also contributed to the positive dynamics.

However, full-scale military operations in Ukraine have significantly undermined the positive dynamics of the agricultural sector. The destruction of critical infrastructure, mining of large areas of agricultural land, disruption of supply chains and environmental pollution with toxic substances have become serious obstacles to agricultural production.

Since 2022, there has been a sharp decline in the area under crops, which has directly affected the decline in yields and production of major crops (Figures 1–3). In addition, reduced access to essential inputs, such as fertilizers, fuel and lubricants, and crop protection products, has made it difficult to resume production processes. The destabilization of the land market, reduced investment, and the forced closure of many agricultural enterprises have exacerbated the crisis in the sector, posing long-term threats to the country's food security and export potential.

It is worth noting that in the context of the aggravation of the crisis in agriculture, the issue of effective resource management and minimisation of losses is gaining special attention. One of the key aspects is the proper disposal and recycling of agricultural waste, which can contribute to the rational use of resources and partially compensate for the shortage of production materials. To streamline these processes, the State Waste Classifier is used, which includes Group 01, which combines waste generated during the production of agricultural and hunting products. It includes the following classification groups [10]:

– waste from the production of cereals, vegetable and horticultural products;

– waste from animal husbandry and livestock production;

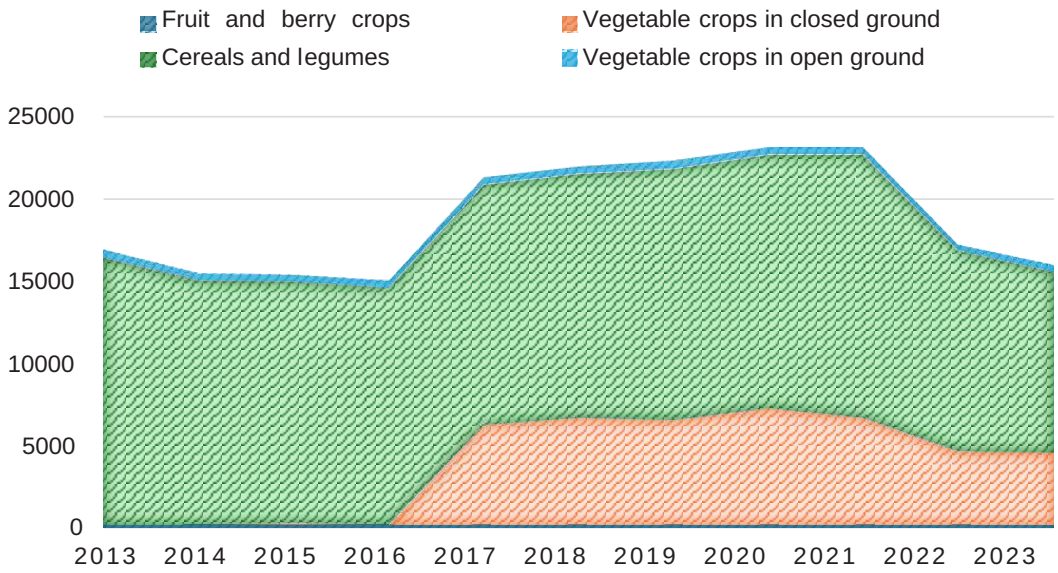

Figure 1. Sown area of crops in Ukraine from 2013 to 2023, thousand hectares

Source: compiled by the author based on ukrstat.gov.ua [9]

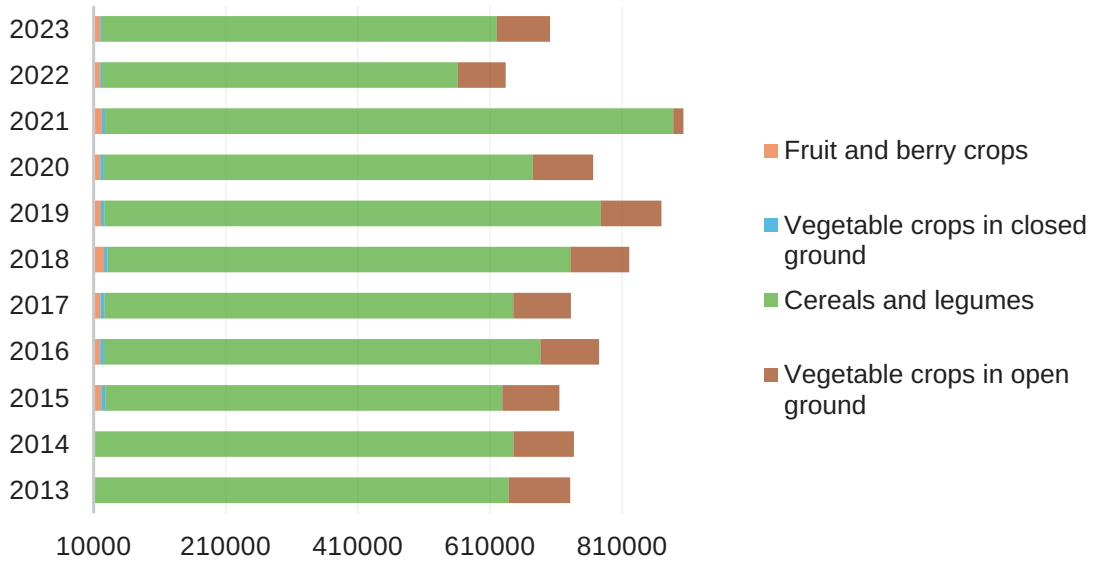

Figure 2. Volume of crops production in Ukraine from 2013 to 2023, thousand centners

Source: compiled by the author based on ukrstat.gov.ua [9]

– waste from the production of mixed farming products;
– waste from the provision of services in crop and livestock production;
– hunting, trapping and game breeding waste;
– specialised services related to the management of agricultural and hunting waste, which are provided at the place of waste generation.

Based on the above, it was decided to analyse the data on waste generation in agriculture (Table 1) and the specifics of agricultural waste management by material category in Ukraine (Table 2).

According to Table 1, the dynamics of changes in the share of agricultural waste in the total structure of waste generated can be traced. In particular, in 2023, compared to 2013, this indicator increased by 1.05%, which indicates a

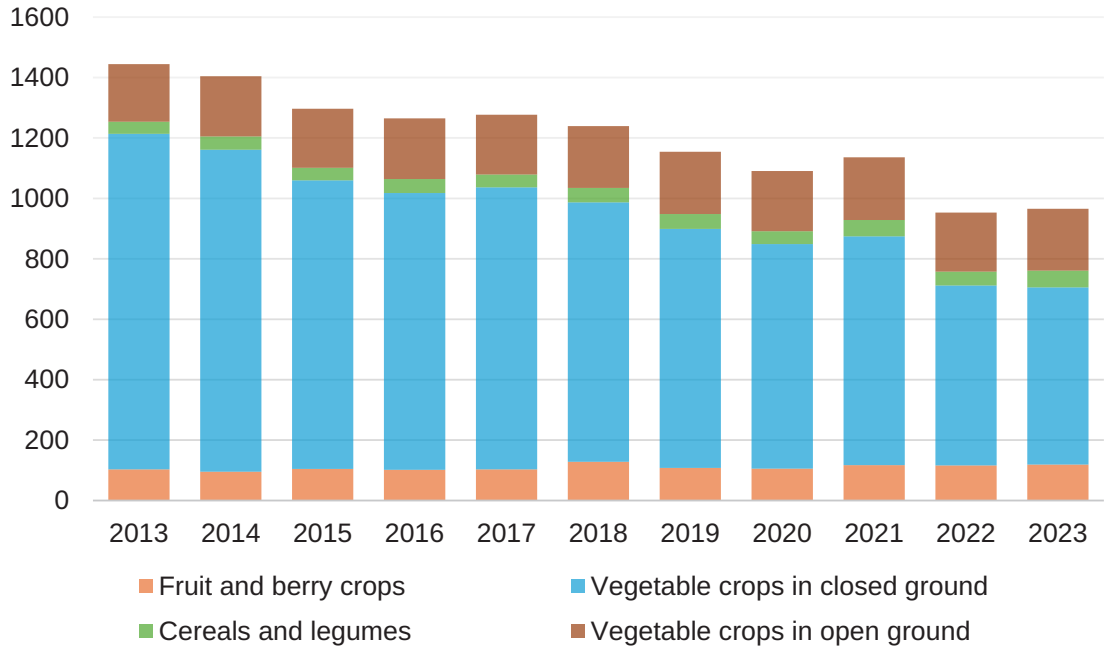

Figure 3. Crop yields in Ukraine from 2013 to 2023, centners per hectare

Source: compiled by the author based on ukrstat.gov.ua [9]

Table 1

Waste generation in agriculture, 2013–2023*

Year	Indicators		
	Total waste, thousand tonnes	Agricultural waste, thousand tonnes	Share of agricultural waste in total waste, %
2013	448117,6	14887,7	3,32
2014	354803,0	14052,8	3,96
2015	312267,6	13577,3	4,35
2016	295870,1	13885,3	4,69
2017	366054,0	13023,3	3,56
2018	352333,9	11670,6	3,31
2019	441516,5	12122,5	2,75
2020	-	-	-
2021	493271,1	8056,4	1,63
2022	203587,6	6219,6	3,05
2023	176289,8	7722,7	4,38

*excluding the temporarily occupied territory

Source: compiled by the author based on ukrstat.gov.ua [9]

tendency to increase the volume of waste in the industry.

For a deeper analysis of the current state of agricultural waste management, the data for 2023 on agricultural waste management was studied (Table 2). The summary information indicates that a significant share of waste generated in the course of agricultural activities has a recovery potential. In particular, animal waste and mixed food waste account for 10.1%, vegetable waste – 27.4%, and animal excrement, urine and manure – 61.3%.

Meanwhile, companies operating in the agricultural sector may face some challenges related to the processing of agricultural waste (Table 3).

Table 2

Agricultural waste management by material category in Ukraine, 2023*

Type of waste	Waste generation, thousand tonnes	Waste recovery		Waste incineration		Waste disposal to the landfills	
		thousand tonnes	%	thousand tonnes	%	thousand tonnes	%
Waste of animal of animal origin and mixed food waste	241,5	24,3	10,1	3,2	1,3	0,9	0,4
Waste of vegetable origin of vegetable origin	4529,3	1242	27,4	362,5	8	17,4	0,4
Animal excrement, urine and manure	2951,9	1809,5	61,3	5,0	0,2	154,1	5,2

*excluding the temporarily occupied territory

Source: compiled by the author based on ukrstat.gov.ua [9]

Table 3

Key waste issues in agriculture

№	Groups of issues	Feature
1.	No waste accounting mechanisms in place	Mechanisms for accounting for the volume and structure of agricultural waste, including household waste, have not been introduced, there is no system for informing about their processing, and a separate legal framework for the management of such waste has not been established.
2.	No regulations on animal waste disposal	The problem of animal waste disposal has not been resolved; Ukraine lacks a sufficient number of animal waste disposal facilities, and the condition of the existing ones remains unsatisfactory.
3.	Problem of agricultural waste transportation	Many agricultural companies have a spatially differentiated land bank, so the processing facility should be located in a transport hub for convenient collection of waste from different regions, or the creation of a joint facility requires cooperation between producers.
4.	Unregulated water pollution by pesticides	Unregulated drainage causes excessive concentrations of nutrients, mostly from fields and livestock farms, and the lack of systematic measurement of diffuse pollution makes it difficult to respond to the effects of nitrate pollution, such as deteriorating water quality and uncontrolled water blooms. European legislation is also not implemented.

Source: compiled by the author on the basis of Green Mind [11]

Indeed, the effective management of agricultural residues is a key factor in ensuring environmental sustainability and the rational use of natural resources. Agricultural enterprises must introduce innovative technologies, improve supply chains and develop comprehensive biomass utilisation and reuse strategies to optimise agrarian waste management. This approach not only helps to minimise the negative impact on the environment but also increases the economic efficiency of agriculture by creating added value from waste and by-products.

In this context, the circular economy emerges as a conceptual framework for transforming agriculture towards sustainable development. It is worth noting that the circular approach was initially based on the principles of the 3R model (reduce, reuse, recycle) but the evolution of the concept led to its expansion to the 10R model (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover), which covers a wider range of resource efficiency and recovery strategies. This expanded approach allows agribusinesses to integrate closed production cycles, reduce

dependence on primary raw materials, and develop a sustainable anti-crisis policy.

The importance of applying circular economy principles in agriculture was highlighted at the Green Mind international forum, where Landell Mills presented a comprehensive set of strategies and practices focused on long-term environmental and economic benefits for the agricultural sector (Figure 4). These principles provide a science-based framework for developing policies that will facilitate the global transition to more sustainable and balanced agricultural systems.

To justify the need to intensify the introduction of innovative technologies for processing agricultural waste by domestic agricultural enterprises, the author analyzed the world experience. The results of the study showed that effective agricultural waste management is based on the integration of high-tech solutions, optimization of resource use and compliance with international environmental standards.

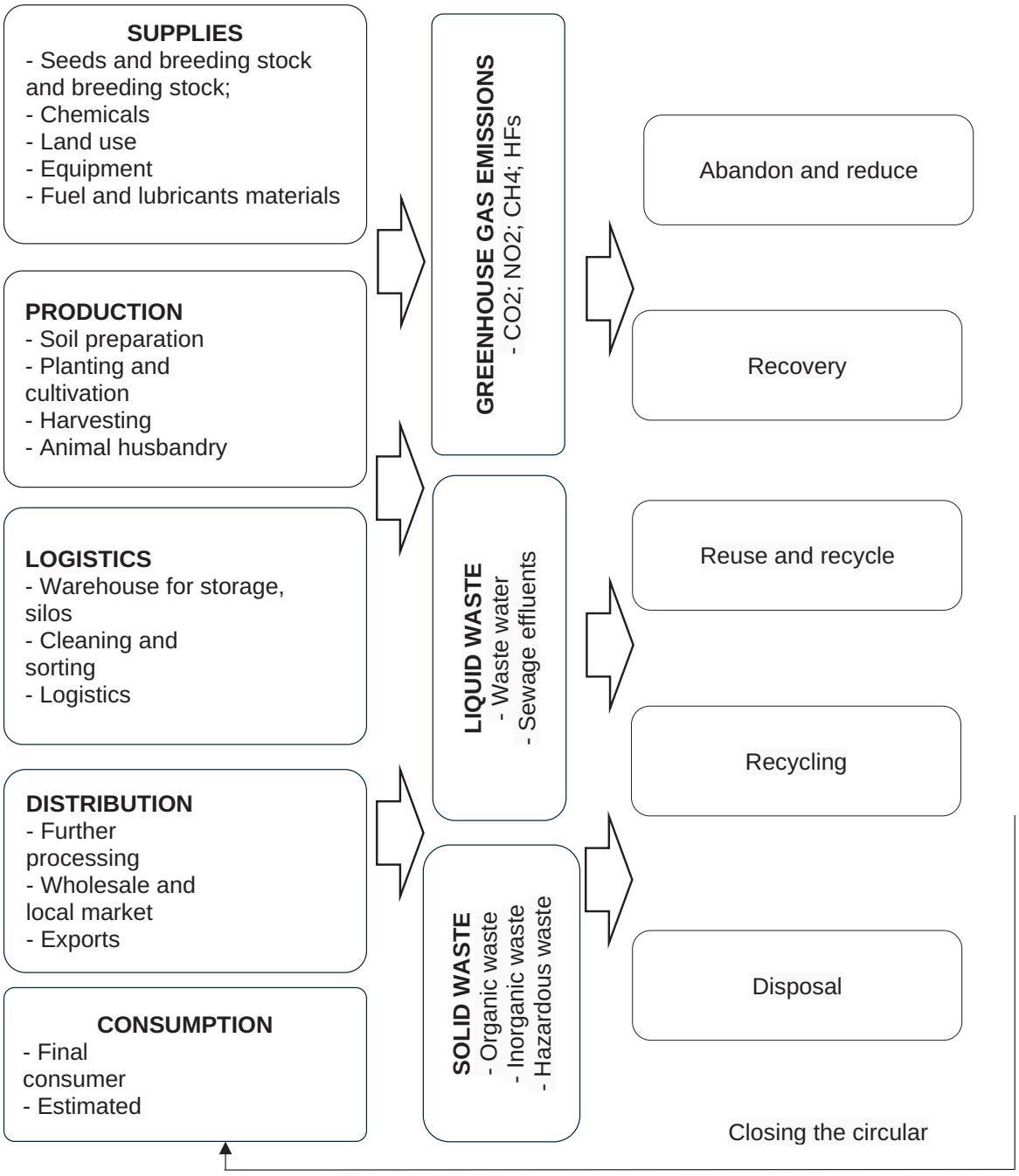

Figure 4. Principles of the circular economy in agriculture

Source: compiled by the author based on Green Mind [11]

The global experience of effective agricultural waste management includes the following practices [12]:

1. Recycling of waste into useful products – production of biofuels, biogas, compost and other secondary resources, which reduces dependence on fossil energy sources and contributes to the decarbonization of the sector.

2. Use of waste as soil fertilizer – returning organic residues to the soil to increase its fertility, improve its structure and increase its nutrient content.

3. Regulation of waste production – implementation of waste management programmes aimed at reducing the amount of waste produced at the production stage through optimization of technological processes.

4. Legislative regulation – regulations that oblige agricultural enterprises to apply environmentally sound waste management practices, control emissions and comply with sustainability standards.

The combination of these approaches allows for the creation of closed production cycles, reducing the ecological footprint of the agricultural sector and creating the preconditions for its sustainable growth.

In addition, for in-depth analysis, Table 4 summarizes the experience of key countries in the world in the field of agricultural waste recycling.

Table 4

World experience in agricultural waste processing

Country	Measures for recycling of agricultural waste
Sweden	Due to the high level of recycling, upcycling and public awareness, Sweden produces almost zero waste. According to data collected by Avfall Sverige, 99% of waste is recycled in Sweden, including: 50 % for energy generation; 35 % for recycling; and another 15 % for the production of biofuels and fertilisers.
German	In their processing activities, German companies use special facilities with technologies that produce biogas and organic fertilisers. The country is a leader in the recycling of agricultural waste, so there are many programmes and technologies aimed at this goal (Energiekonzept 2050, BioDivers, Bioeconomy, BodenSchutz).
Switzerland	One of the most successful areas of agricultural waste processing in Switzerland is biogas production. Waste is processed in special facilities where it undergoes biological decomposition. This process produces biogas, which can be used to generate electricity or to produce heat and hot water.
Spain	The company has a developed system for processing olive oil and other crop waste into biofuels. This helps to reduce pollutant emissions and reduce dependence on petroleum fuels. Spain has various programmes for the recycling of agricultural waste aimed at reducing the negative impact of this waste on the environment and the economy (REAGYP, PIMA Residuos).
China	Examples of China's experience in managing agricultural waste: there are special incentive programmes for farmers to help reduce waste and promote environmentally sustainable agriculture (the Mineral Fertiliser Efficiency Subsidy programme); programmes for collecting and processing agricultural waste (processing grain residues and straw into animal feed, biogas and organic fertilisers); programmes have emerged to use modern waste management technologies (programmes that use sensors to monitor soil and water quality in real time).
USA	The USA has a very developed market for recycling agricultural waste. For example, many farmers process their waste into animal feed, such as compound feed. Many farmers in the USA also use special facilities to convert organic waste into biogas. Biogas can be used to produce electricity and heat. There are also programmes aimed at reducing waste and supporting recycling.
Netherlands	There is extensive experience of using biogas from livestock and crop waste. Biogas is produced in special plants, which can then be used to generate electricity and heat. In the Netherlands, there are several programmes and initiatives aimed at utilising agricultural waste (Circular Agriculture, Biobased Delta, Waste-to-Chemicals).

Source: compiled by the author based on [12]

Based on the analysis of the main aspects of the circular economy model, a number of potential benefits for Ukrainian agricultural enterprises in the context of strengthening their anti-crisis potential can be identified:

1. Reducing dependence on external resources – recycling waste to produce biofuels, compost or feed reduces the cost of purchasing energy and fertilisers.
2. Diversification of income sources – the introduction of waste recycling technologies creates new business opportunities, including the production of value-added secondary products.
3. Increased resilience to market fluctuations – optimising production cycles and minimising waste reduces operating costs and ensures stable cash flows even in times of crisis.
4. Environmental sustainability and compliance with regulatory requirements – the implementation of circular approaches helps to reduce greenhouse gas emissions and adapt to international environmental standards, which improves competitiveness in foreign markets.
5. Innovative development and investment attraction – focusing on circular processes opens up access to grants, green technology support programmes and stimulates the development of internal innovative solutions.

As a result, the adaptation of circular economy principles allows Ukrainian agricultural enterprises not only to effectively overcome crisis phenomena, but also to form sustainable, environmentally responsible production systems with a high level of adaptability to global challenges.

Conclusions. The conducted research was aimed at revealing the theoretical and methodological foundations of the circular economy and assessing its potential for strengthening the anti-crisis sustainability of agricultural enterprises. The analysis examines the evolution of the concept of «circular economy», considers key models and approaches to agricultural waste processing, and outlines the prospects for introducing innovative technologies in the agricultural sector of Ukraine. It has been determined that the adaptation of circular principles can significantly increase resource efficiency, help reduce the environmental burden and ensure the long-term economic stability of enterprises in crisis conditions.

Further research in this area should be focused on developing practical mechanisms for implementing the circular model in agribusiness, assessing the economic feasibility of various waste processing technologies, and formulating state support policies to stimulate sustainable development of the agro-industrial complex. Particular attention should be paid to the adaptation of global experience to the specifics of the national economy and the development of tools for monitoring the effectiveness of circular transformations in real production conditions.

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