

CIRCULAR ECONOMY - DRIVER OF THE TRANSITION TO SUSTAINABLE AGRICULTURE

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REVIEW

Abstract

The circular economy is becoming a central strategic framework for the transition to sustainable agri-food systems, by replacing the linear "extract-produce-dispose" model with a regenerative one, based on keeping resources in the loop and radically reducing waste. Recent definitions describe the circular economy as a regenerative system that minimizes resource inputs and losses of materials, emissions and energy, through strategies for reduction, reuse, repair, remanufacturing, recycling and energy recovery of waste streams.

In agriculture, the principles of the circular economy translate into practices such as circular nutrient management, the transformation of agricultural waste into resources, the integration of crops and livestock, as well as business models based on the reduction of food losses and waste. This paper aims to analyze the role of the circular economy as a driver of the transition to sustainable agriculture, based on recent scientific literature, reports by international organizations and relevant public policy documents.

The methodology used is a narrative review, focused on identifying the main concepts, models and tools of the circular economy applied to agriculture, as well as case studies illustrating the impact on resource efficiency, greenhouse gas emissions, biodiversity and farm resilience. The results suggest that the large-scale adoption of the circular economy in agriculture can accelerate the achievement of the Sustainable Development Goals, the EU climate targets and the transition to resilient and healthy agri-food systems, but requires profound policy changes, investments in infrastructure and knowledge, as well as new models of governance and cooperation along the agri-food chain.

Keywords: circular economy, sustainability, agriculture, resources, losses of materials.

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INTRODUCTION

The linear economic model, based on the intensive exploitation of natural resources and the externalization of environmental costs, has contributed to soil degradation, biodiversity loss, increased greenhouse gas emissions and increasing pressures on food security. Agriculture is simultaneously a victim and a source of these pressures: the agri-food sector uses water, soil, energy and chemical inputs intensively, while generating significant emissions and waste (FAO, 2018; Geissdoerfer et al., 2017).

The European Green Deal proposes a structural transformation of the EU economy to achieve climate neutrality by 2050, with ambitious emission reduction targets by 2030. A central pillar of this pact is the transition to a circular economy, which reduces pressure on resources, limits biodiversity loss and supports economic competitiveness and resilience (European Commission, 2019).

In the agri-food sector, the Farm to Fork and Biodiversity strategies aim to reduce the use of pesticides and fertilizers, reduce food losses and waste, and promote the practice of circular agriculture.

The circular economy is frequently defined as a system in which products, materials and resources are kept in use for as long as possible, through successive value-maintaining strategies, while the generation of waste and pollution is minimized (Ellen MacArthur Foundation, 2013; Kirchherr et al., 2017). This approach aligns with the goals of sustainable agriculture, which aim to produce safe and nutritious food while simultaneously ensuring the ecological functions of agricultural ecosystems – soil fertility, water and nutrient cycles, pollination services and adaptation to climate change (FAO, 2018).

Internationally, numerous initiatives highlight the potential of circular agriculture: Ellen MacArthur Foundation reports on the circular economy for food, FAO projects dedicated to reducing food loss and waste and

integrating circular economy principles into food systems, as well as UN and specialized agency programs on the circular bioeconomy. (European Commission, 2020)

In Romania, debates on the circular economy and bioeconomy are gaining momentum, including in the agricultural and agri-food sectors. Recent studies highlight the role of European policies and the bioeconomy strategy in stimulating the shift towards more circular production and consumption models in the national context (Rodino, 2023).

In this context, this article aims to:

- to synthesize the main concepts and definitions of the circular economy and circular agriculture;
- to highlight the mechanisms through which the circular economy can act as a driver of the transition to sustainable agriculture;
- to analyze examples and results from recent literature;
- to discuss the challenges and conditions of implementation in practice.

MATERIAL AND METHOD

The paper is a narrative and conceptual review of the relevant literature and public policy documents. Scientific databases (Scopus, Web of Science, ScienceDirect, MDPI) and open resources (FAO, UN, European Commission, Ellen MacArthur Foundation) were searched, using key word combinations such as: circular economy, circular agriculture, sustainable agriculture, agri-food systems, circular bioeconomy, food loss and waste, EU Green Deal.

The selection criteria included:

- direct relevance for the link between the circular economy and agriculture/agri-food;
- the recent nature (especially works from the last 5–7 years), with the inclusion of older basic references, but considered "classical" for defining concepts;
- the diversity of types of sources: scientific articles, books, reports and official documents.

In total, over 40 sources were selected, of which 15+ are used and explicitly cited in the text, ensuring balanced coverage between:

- theoretical works on the definition and conceptualization of the circular economy;
- empirical studies on the implementation of the circular economy in agriculture;
- policy reports and official documents (EU, FAO, UN);

- volumes dedicated to circular agriculture and agricultural waste management.

The analysis was structured around four main axes: (1) the conceptual framework, (2) the concrete mechanisms through which the circular economy supports sustainable agriculture, (3) examples and results from case studies, and (4) policy challenges and recommendations.

RESULTS AND DISCUSSIONS

Conceptual framework: from circular economy to circular agriculture

Geissdoerfer et al. (2017) define the circular economy as a regenerative system in which resource inputs and losses of materials, energy and emissions are minimized by slowing down, closing and narrowing material and energy loops (Kirchherr et al. 2017), after analyzing over 100 definitions, show that the "reduce-reuse-recycle" triad remains central, but must be complemented with social and governance dimensions to fully meet sustainability objectives.

The Ellen MacArthur Foundation has popularized the circular economy model globally, demonstrating the economic and job creation potential of the transition from a linear to a circular system, including food chains (Ellen MacArthur Foundation, 2013). In agriculture, the notion of circular agriculture describes agri-food systems that manage nutrient, water and energy cycles in a way that reduces dependence on fossil inputs, limits waste and regenerates natural resources (Rashed, 2024; Guerrero-Villegas et al., 2025).

FAO and other international agencies promote the integration of circular economy principles into the broader framework of sustainable food systems, seen as systems that ensure food and nutrition security while maintaining the long-term economic, social and environmental basis (FAO, 2018).

Mechanisms through which the circular economy supports sustainable agriculture

The literature highlights several key mechanisms through which circular economy principles can act as a driver of the transition to sustainable agriculture:

1. Circular nutrient management

Recycling organic waste (vegetable residues, manure, treated sludge) into organic fertilizers or biogas digestate reduces dependence on mineral fertilizers, limits nitrogen and phosphorus losses and contributes to soil quality (Velasco-Muñoz et al., 2021).

European reports show that nitrogen and phosphorus surpluses per unit area generate emissions and water pollution, and "circular nutrient management" strategies are proposed as a policy solution within the Green Deal and the EU bioeconomy strategy.

2. *Recycling waste and secondary flows*

The transformation of agricultural waste into biomass energy, compost, biodegradable packaging materials, or feed ingredients reduces both the pressure on landfills and the need for virgin resources (Mohajan, 2020; Nguyen et al., 2025).

Khatami's (2024) study on the circular economy in the agri-food system at the country level shows that reducing food waste and generating renewable energy from waste can significantly reduce the sector's carbon footprint.

3. *Integration of crop and livestock production*

Integrated farming models, in which residues from one activity become inputs for another (e.g. manure used to fertilize crops, crop residues used to feed animals or as a substrate for biogas), are frequently presented as examples of circular agriculture (UNIDO, 2020).

Recent literature on the circular economy in animal husbandry indicates the potential to reduce emissions and improve resource efficiency, provided that environmental and health risks are rigorously managed.

4. *Reducing food loss and waste*

The FAO project "Circular Economy in the Food Sector (CIRCULAR)" illustrates how food recovery, redistribution and recycling can be integrated into public policies and business models, with an impact on reducing emissions and increasing food security.

The Ellen MacArthur Foundation emphasizes that reforming food systems on circular principles can play a major role in combating climate change and restoring biodiversity, especially in urban environments, by shortening supply chains and designing menus and products with waste minimization in mind.

5. *Creating new business models in the agri-food sector*

Fortunati et al. (2020) show that integrating the circular economy and corporate social responsibility in farms and agri-food businesses can generate economic, social and environmental value, by diversifying income (ecosystem services, renewable energy, value-

added products from waste) and strengthening relationships with local communities.

More recent studies on circular models in agriculture identify various typologies: from "zero waste" farms and bioenergy cooperatives, to digital platforms for redistributing surpluses and sharing agricultural equipment (Guerrero-Villegas et al., 2025; Siankwilimba et al., 2025).

Results from the literature: benefits and risks

Highlighted benefits

- Increased efficiency in resource use: Multiple synthesis studies highlight the reduction in waste volume, water and energy consumption, and the use of chemical fertilizers where circular principles are applied in agri-food chains (Velasco-Muñoz et al., 2021; Judijanto, 2025).

- Reducing emissions and contributing to climate goals: The transformation of residues into biogas and biofertilizers helps reduce methane and nitrous oxide emissions, and circular economy strategies are seen as essential tools for meeting the EU's climate goals and the 2030 Agenda.

- Improving soil health and biodiversity: Practices that reintroduce organic matter to the soil and diversify crop rotations contribute to increased organic carbon content, better soil structure, and increased functional biodiversity (Nguyen et al., 2025).

- Economic and social resilience: The circular economy can reduce farms' dependence on imported and price-volatile inputs, and diversifying income streams (e.g. from renewable energy or by-products) provides more economic stability and employment opportunities, including for women and young people.

Risks and challenges

FAO draws attention to the fact that the integration of circular principles into food production also raises new food safety risks: the accumulation of contaminants (heavy metals, pesticides, microplastics) in recycled material flows, the risk of pathogen transmission and the emergence of antimicrobial resistance in certain circular chains (for example, the use of sewage sludge or non-compliant composts in agriculture) (FAO, 2024).

Other challenges identified in the literature include:

- Lack of infrastructure and investment for the separate collection,

treatment and recovery of agricultural and food waste, especially in rural areas and in low- and middle-income countries (FAO, 2024).

- Fragmentation of agri-food chains, which makes it difficult to coordinate between producers, processors, traders and authorities in designing circular “farm to fork” models (Khatami, F., et al. 2024).

- Unsuitable regulatory framework, where rules on fertilisers, food safety and waste do not always reflect the complexity of circular models and can create both barriers and 'grey areas'(IEEP, 2025).

- The need for new knowledge and skills at the level of farmers, consultants and authorities, for the design and management of complex circular systems. Specialized volumes, such as “Developing Circular Agricultural Production Systems” and “Agriculture Waste Management and Bioresource: The Circular Economy Perspective”, emphasize the role of professional training and interdisciplinary research in overcoming these obstacles.

CONCLUSIONS

The circular economy provides a coherent and comprehensive framework for the transition to sustainable agriculture by reconfiguring the way food and agricultural resources are designed, produced, consumed and exploited. The analysis of the literature and policy documents shows that:

1. The circular economy and sustainable agriculture are deeply complementary: EC provides tools and operational models for achieving sustainability goals, while agriculture offers a privileged field of application for resource loops (water, nutrients, biomass).

2. Key mechanisms– circular nutrient management, waste recovery, integration of plant and animal production, reduction of food losses and waste, development of new business models – can generate significant environmental, economic and social benefits.

3. European and international public policies (European Green Deal, bioeconomy strategies, reports by FAO and other organizations) increasingly explicitly recognize the role of the circular economy in transforming food systems and support its integration into national plans, including in Romania.

4. Risks and challenges– related to food safety, insufficient infrastructure, unsuitable regulatory frameworks and lack of skills – do not invalidate the model, but require a cautious

approach, based on scientific assessment, monitoring and participatory governance.

In conclusion, the circular economy can be considered not only a tool for optimizing resource use in agriculture, but also a structural driver of the transition towards sustainable and resilient agri-food systems. Realizing this potential requires:

- coherent integration of circular principles into agricultural, environmental, energy and rural development policies;

- economic incentives and financing mechanisms for pilot projects and investments in circular infrastructure;

- training and rural extension programs geared towards circular agriculture;

- interdisciplinary research and monitoring of impacts on the environment, economy and public health...

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