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CIRCULAR ECONOMY IN AGRICULTURE: REDUCING WASTE AND IMPROVING SUSTAINABILITY

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ABSTRACT

The agricultural sector is under growing pressure to increase food production with limited resources while minimizing environmental degradation. The circular economy offers a sustainable approach by converting agricultural waste into valuable inputs, reducing reliance on external resources, and improving soil health and farm profitability. This article examines the core principles of the circular economy, its significance in contemporary agriculture, and its contribution to waste reduction and sustainability. It also distinguishes circular economy concepts from integrated farming systems. Additionally, the article discusses future prospects, emerging technologies, and key challenges in implementation, emphasizing the importance of supportive policies, institutional coordination, and capacity building.

KEYWORDS: Circular agriculture, greenhouse gas mitigation, integrated farming systems, resource recycling, sustainable agriculture

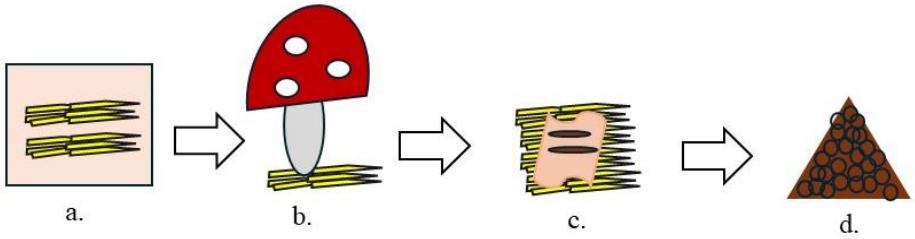
INTRODUCTION

Agriculture plays a dominant role in shaping environmental conditions, contributing significantly to greenhouse gas emissions, soil degradation, and water pollution. Conventional linear production systems follow a “take–make–dispose” model that generates large quantities of waste and relies heavily on synthetic inputs. As global population continues to rise and natural resources become scarce, there is an urgent need to adopt sustainable models of production. The circular economy offers a transformative approach by emphasizing waste reduction, material reuse, and regeneration of natural systems. Within agriculture, this approach supports resource efficiency, environmental protection, and long-term productivity.

WHAT IS CIRCULAR ECONOMY?

A circular economy is an economic system designed to minimize waste and maximize the continuous use of resources through recycling, reuse, recovery, and regeneration. Unlike the linear production model, the circular approach creates closed-loop systems where by-products from one process serve as inputs for

another. In agriculture, this includes recycling crop residues, generating renewable energy from waste, and returning organic matter to the soil. Circular agriculture emphasizes efficiency, low environmental impact, and the creation of value from materials traditionally considered waste. For a clear understanding of circular economy, Figure 1 is represented below.



a. Paddy straw from the field, b. Mushroom farming by using paddy straw substrate, c. Vermicomposting by using mushroom substrate and d. Final end product of compost ready for application

Figure 1. Circular cycles of the circular economy

WHY CHOOSE CIRCULAR ECONOMY IN AGRICULTURE?

Agriculture generates substantial waste from crop residues, livestock operations, and food processing activities. Rising input costs and declining soil health demand effective resource recycling. Circular practices reduce reliance on synthetic fertilizers, conserve water, enhance soil fertility, and help mitigate climate change impacts. Moreover, circularity supports economic resilience through value-added enterprises such as composting, vermicomposting, bioenergy production, and waste-based fertilizers. These practices align with global sustainability goals and agricultural development priorities.

THE PRINCIPLES GUIDING CIRCULAR AGRICULTURE INCLUDES

- **Reduce:** Systems are structured to minimize waste generation and the emphasis is on prioritizing use of regenerative and restorative resources also use of Bbiogas, solar, and biomass energy reduce dependence on fossil fuels.
- **Reuse:** This encompasses to reuse the useful parts of components or a product, wherever possible like materials such as nutrients, water, and biomass circulate within the system.
- **Recycle:** utilizing discarded material as a source of secondary resource, through extensive recycling. Organic residues are returned to ecosystems to improve soil fertility.
- **Re-manufacture:** To create new products by utilizing waste streams such as Waste materials are transformed into marketable or useful products such as compost, manure, biochar, or energy.
- **Repair/refurbish:** The aim is to preserve and extend the life of a product.

(Basic moto is to eliminate pollution, circulate products and materials and regenerative nature)

Table 1. Difference Between Linear economy, Circular Economy and Integrated Farming System (IFS)

Aspect	Linear Economy	Circular Economy	Integrated Farming System (IFS)
Concept Type	Follows "take, make and dispose" model	Follows reuse, recycle, reduce and regenerative model	Farm-level system integrating multiple enterprises
Resource Flow	One-way flow; resources used once and discarded	Closed-loop flow; materials reused, recycled, regenerated	Internal recycling of resources among farm components
Waste Management	Waste is largely discarded; high generation	Waste is minimized and transformed into valuable resources	Waste from one enterprise serves as input to another
Focus Area	Production efficiency without reuse	Recycling, reuse, renewal, and regeneration	Interdependence and complementarity of farm components
Scale of Operation	Global and industrial level	Engages industries, consumers, markets, and supply chains	Within the farm boundary
Environmental Impact	High pollution, resource depletion, emissions	Reduced pollution, efficient resource use	Reduced chemical use; improved soil health
Energy Use	Relies on non-renewable energy	Promotes renewable and bio-based energy	Uses biological energy cycles within the farm
Examples	Single-use plastics; chemical-intensive systems	Composting, biogas, biochar, nutrient recycling	Crop–livestock–fish integration, agroforestry

While IFS is an important farm-scale component of circular agriculture, the circular economy extends beyond the farm to include broader economic and industrial linkages. In simple words the use of the circular economy concept beyond different agricultural enterprises known as IFS.

NEED FOR CIRCULAR ECONOMY IN AGRICULTURE

- The world's population is growing with the demand for raw materials but the supply of crucial raw materials is limited.
- Extracting and using raw materials has a major impact on the environment.
- It also increases energy consumption and CO_2 emissions.
- Around 3.3 billion tons of greenhouse gases are emitted, and 1.6 billion tons of food waste is generated.

Table 2. ROLE OF ENVIRONMENTAL PROTECTION AGENCY (EPA)

Year	EPA Actions / Activities
2024	✓ June 2024: Released the *National Strategy for Reducing Food Loss and Waste and Recycling Organics* after receiving and reviewing public comments earlier in the year. ✓ September 2024: Released *Notice of Funding Opportunities* for the Solid Waste Infrastructure for Recycling and the Recycling and Education Outreach Grant Programmes. ✓ November 2024: Released the *National Strategy to Prevent Plastic Pollution* after reviewing public comments (2023).
2025	✓ 24 September 2025: EPA's Circular Economy Programme is hosting the *Annual Circular Economy Conference* at Aviva Stadium, Dublin. ✓ Conference features: presentations, case studies, interactive panel discussions, exhibition area, and networking. Focus on EU Circular Economy Act, competitiveness of circular models, and extended producer responsibility in key sectors. Showcasing *Local Circular Solutions* with enterprises presenting their circular business models. ✓ Registered as a European Sustainable Development Network event; CPD approved by Engineers Ireland and CIWM.

HOW IT WORKS?

1. Aids in Reducing Waste

Circular agriculture reduces waste by transforming it into useful products. Crop residues can be converted

into compost or biochar instead of being burned, thereby improving soil carbon and reducing pollution. Livestock waste can be processed through anaerobic digestion to produce biogas and nutrient-rich digestate. Food processing waste can be used as animal feed, fertilizers, or raw materials for bio-based industries. Treated wastewater can be safely reused for irrigation. Precision agriculture technologies further decrease waste by optimizing input use.

2. Improving Sustainability

Circular practices enhance sustainability by promoting soil health, biodiversity, and ecosystem resilience. Incorporating organic matter improves soil structure, nutrient availability, and microbial activity. Renewable energy sources reduce greenhouse gas emissions and support low-carbon agriculture. Efficient water management, recycling, and precision irrigation conserve scarce resources. Collectively, these practices contribute to long-term productivity and environmental stability.

3. Impacts on Society

The circular economy benefits society by improving waste management, promoting clean environments, and opening new opportunities for rural entrepreneurship. Activities such as composting, bioenergy production, and decentralized waste processing create employment and diversify farm income. Reduced pollution from residue burning and improper waste disposal enhances public health. Sustainable food systems also improve food quality and strengthen community resilience.

FUTURE WORK

Future developments in circular agriculture will focus on technological innovation, policy integration, and market development. Waste-to-wealth technologies such as biochar production, biorefineries, and advanced composting will expand. Digital tools including artificial intelligence and the Internet of Things will enhance monitoring and precision in resource recycling. Stronger market linkages and policy frameworks will support commercialization of circular products. Research on climate-resilient circular models and nutrient recovery will be essential for large-scale adoption.

CHALLENGES

Despite its advantages, implementing circular agriculture faces several obstacles. These include limited knowledge and training, high initial investment for technologies, weak market demand for recycled products, and policy gaps. Poor waste segregation and lack of cross-sectoral coordination further hinder progress. Addressing these issues requires partnerships among governments, industries, researchers, and farming communities.

CONCLUSION

Circular economy offers a promising pathway for transforming agriculture into a sustainable and resource-efficient system. By closing nutrient loops, recovering valuable resources, and promoting regenerative practices, circular agriculture reduces environmental impacts and enhances profitability. Although challenges remain, sustained innovation, supportive policies, and community engagement will accelerate the transition. Circular agriculture is essential for ensuring long-term food security, environmental health, and resilient farming systems.

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