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# Circular Economy in the Agricultural Sector

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## ABSTRACT

**BACKGROUND AND OBJECTIVES**

The circular economy has become a key issue in recent years, seen as capable of addressing economic and environmental challenges while simultaneously fostering the creation of a sustainable ecosystem. The Indonesian government has begun adopting this concept in its 2020 - 2024 development plan, with the agricultural sector as one of the areas with significant potential for its application. This study aims to describe the circular economy concept and its relevance to agriculture, identify the potential and challenges of its implementation in Indonesia, and formulate strategic recommendations.

**METHODS**

A literature review of academic sources and policy documents to gain a comprehensive understanding of the circular economy implementation model and approach in the agricultural sector.

**FINDINGS**

This study reveals that implementing a circular economy in the agricultural sector has significant potential to increase resource efficiency, reduce waste, and improve environmental sustainability. However, various challenges remain, including limited access to financing, inadequate infrastructure, weak agricultural extension services, and insufficient business support. Comparisons with international practices, such as China's zero-waste city initiative and Europe's integrated food model, demonstrate that regulatory frameworks, technological innovation, and stakeholder collaboration are key drivers of circular economy adoption in agriculture.

**CONCLUSION**

Based on these findings, the successful implementation of a circular economy in agriculture requires strengthened regulations, financial and technological support, and cross-sector collaboration, as demonstrated by international practice. With these steps, the agricultural sector can transform into a more resilient, sustainable system capable of maintaining ecological balance and food security.

**Keywords:** Agriculture; Circular; Economy; Sustainable; Waste

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## INTRODUCTION

The circular economy has become a popular topic in recent years (1). A circular economy is an economic system that uses as many raw materials, components, and products as possible (2). This is done to reduce the amount of unused materials sent to landfills (3). The term circular economy was first introduced by Pearce & Turner in 1990 and has since received widespread attention worldwide as an alternative to excessive consumption of natural resources (4). The circular economy plays a role in achieving sustainable performance through systems that meet the needs of the present without compromising future generations' ability to meet their own needs. This approach emphasizes balancing and improving performance across the three main pillars of sustainability: environmental, social, and economic (5). By optimizing resource use, minimizing waste, and encouraging innovation across the production and consumption cycles, a circular economy not only maintains ecosystem sustainability but also creates value that contributes to societal well-being and long-term economic resilience.

The circular economy is a manifestation of the state's responsibility to address economic and environmental problems while simultaneously building a sustainable ecosystem for the future (6). The Indonesian government supports the implementation of a circular economy model by adopting it in the 2020-2024 development plan and including it in the medium-term planning program (7). In the RPJMN, there are two National Priority Agendas that cover the circular economy, namely National Priority Agenda 1 (strengthening economic resilience for quality and equitable growth) and National Priority Agenda 6 (building the environment, increasing disaster resilience, and addressing climate change) (8). There are several reasons why a circular economy is crucial: protecting the environment, encouraging innovation, increasing economic efficiency, creating jobs, and promoting social justice. Furthermore, the circular economy is seen as a crucial strategy for achieving the Sustainable Development Goals (SDGs) (9). Suppose previously the development approach was more based on a linear economic paradigm oriented towards exploitation, consumption, and disposal. In that case, the increasing public awareness of sustainability issues has encouraged the emergence of new alternatives through the application of the 3R principles (reduce, reuse, recycle), the green economy, and the green environment, which are then integrated into the concept of a circular economy (10).

One sector with high potential for implementing a circular economy in Indonesia is agriculture. A circular economy in the agricultural sector emphasizes maximizing the use of existing inputs, such as natural fertilizers, by optimizing the supply chain to be as short and efficient as possible, thereby minimizing dependence on new inputs that must be reproduced (11). In addition, implementing a circular economy is relevant because it can minimize waste by optimizing production processes that yield materials for reprocessing into value-added products, thereby reducing environmental impact and strengthening economic value (12). In Lampung Province, the circular economy in the agricultural sector has been demonstrated through several local initiatives. One example is cassava waste management in East Lampung Regency, where tapioca factory waste is reused as animal feed and biogas feedstock (13). In addition, in North Sumatra Province, a circular economy is being implemented by utilizing cabbage waste as

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compost (14). These examples demonstrate the real potential of implementing a circular economy to improve the efficiency and sustainability of local agricultural systems.

However, the existing literature shows that implementing a circular economy in Indonesia's agricultural sector still faces several fundamental challenges, including limited waste management infrastructure, low farmer literacy about circular practices, limited access to financing, and a lack of integration of cross-sectoral policies. Most previous research focuses on the circular economy in manufacturing, energy, and urban waste management, while studies specifically addressing its application in Indonesian agriculture remain limited.

A review of previous research reveals several important findings regarding the shift in food production systems towards a circular model (15), the role of biochar in closing the agricultural nutrient cycle (3) and the implementation of a circular economy in the European agro-food sector is still low (11) However, these studies have not examined conditions in Indonesia, related to implementation constraints, farmer readiness, and the national policy context. Thus, there are still research gaps in the following areas: (1) a lack of circular economy implementation models that are appropriate to local conditions, (2) minimal evaluation of supporting policies in the agricultural sector, and (3) the absence of a comprehensive synthesis of opportunities, challenges, and strategies for implementing a circular economy specifically for Indonesian agriculture. This gap indicates that studies integrating theory, policy, and real-world practices across countries are essential to formulating appropriate strategies for Indonesia.

The novelty of this research lies in its analytical focus, which explicitly examines the application of a circular economy in the Indonesian agricultural sector, based on a synthesis of international and national literature. This research contributes through an in-depth mapping of opportunities and challenges, an analysis of implementation models relevant to local conditions, and strategic recommendations that serve as a reference for policymakers, business actors, and agricultural practitioners. The objectives of this research are (i) to describe the concept of a circular economy and its relevance in the agricultural sector, (ii) to identify the potential and challenges of its application in Indonesian agriculture, (iii) to analyze various approaches and implementation models based on literature studies, and (iv) to provide strategic recommendations to support the implementation of a circular economy in sustainable agriculture.

## RESEARCH METHOD

This research is a library-based qualitative descriptive study that uses literature review techniques to examine relevant research. Literature review is an activity carried out systematically by examining, analyzing, and comparing books, scientific articles, and other sources relevant to a particular problem, research field, or theory, in order to obtain the required data and present descriptions, summaries, and critical evaluations, so that the information obtained can be processed and concluded through the application of specific methods to help find solutions to the problems being studied (16,17). The literature used consisted of books, journals, proceedings, and other scientific papers obtained online from sources such as Google Scholar, Scopus, and ScienceDirect. The criteria for the literature used were that it was published within the last 10 years, discussed the application of a circular economy, and was written in both English and

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Indonesian. The purpose of this literature review was to examine the definition and theory of a circular economy, particularly in the agricultural context.

Qualitative research is conducted for its exploratory nature, namely, to understand phenomena in depth without being tied to existing theories (18). A literature review is crucial because it integrates findings from various studies, provides a strong theoretical foundation, demonstrates developments in prior research, and identifies new research gaps. Several steps are necessary in conducting a literature review, including:

1. Planning a Literature Review
   At the literature review planning stage, the study's focus and research objectives are determined to ensure a systematic, well-directed literature search (19). This stage includes compiling keywords, selecting scientific databases, and defining inclusion and exclusion criteria to ensure the sources obtained are relevant and credible (20). Next, the collected literature is organized and mapped into main themes to form a theoretical framework, while identifying research gaps that serve as the basis for further analysis (19).
2. Conducting a Literature Review
   The composition of a literature review is considered good if it meets several criteria(20), as follows:
   a. **Coverage**, In relation to the purpose of the writing, the article should include relevant references, both in terms of quantity and quality. An article is considered well-covered if it can connect the findings and arguments from supporting sources with the author's opinion. An article that provides an in-depth explanation of a topic will be more useful than a brief overview.
   b. **Synthesis**, A good literature review is not simply a list of citations; it must also be able to summarize, connect, and critique relevant references. The synthesis stage requires analytically combining ideas from various sources to discover patterns, compare findings, and generate new insights. Thus, the synthesis stage not only strengthens the research's theoretical framework but also provides a basis for formulating further research directions by emphasizing the intended scientific contribution.
   c. **Rhetoric**, The argumentation strategy and presentation style used to convince readers of the relevance, validity, and urgency of the research topic. In this context, a literature review does not simply present a collection of quotations. Instead, it constructs a structured narrative that helps readers understand the study's development, the current state of the research, and any remaining research gaps.
3. Reporting a Literature Review
   Compiling or reporting the literature review is the final stage of the review process. At this stage, the results of the analysis and evaluation of various literature sources are systematically developed. The final step in this process is to list the sources used and draw conclusions to determine whether new findings have been obtained on the topic analyzed.

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## RESULTS AND DISCUSSION

### The Circular Economy Concept in the Agricultural Sector

Over the past decade, the circular economy has received widespread attention worldwide as an approach to addressing current production and consumption models (15). The conceptual shift from a linear to a circular economy is necessary to resolve the crises facing the world. The circular economy emerged as an alternative to the linear take-make-dispose model, which has been proven to cause serious problems, such as the overexploitation of natural resources, increased waste volumes, and increased environmental pressure. By prioritizing efficient resource use, extending product lifespans, reusing materials, and reducing waste, the circular economy is seen as capable of creating a more sustainable production and consumption system through a restorative, regenerative paradigm in harmony with the environment (21). A simple circular economy concept is shown in Figure 1.


Figure 1. The Circular Economy Concept in the Agricultural Sector

Each year, the volume of global food waste is estimated to reach 1.6 tons (22). This reinforces the urgency of transitioning to a more regenerative model. The literature review shows that the circular economy is developing in response to increasing environmental pressures resulting from the linear economic model.

Literature reviews show that global implementation of the circular economy is underway, but its success rate varies widely. Previous research emphasizes that successful models depend heavily on policy support, technology, and institutional capacity.Previous research on the circular economy in agriculture is presented in Table 1.

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Table 1. Research Results on Circular Economy in Various Countries

| No | Researchers | Research Focus | Key Findings | Relevance |
|---|---|---|---|---|
| 1 | Amreen Bano (3) | Utilization of biochar | Biochar closes nutrient cycles & reduces emissions | Becoming an example of the implementation of the Circular Economy |
| 2 | Fahimeh Khatami (11) | Implementation of Circular Economy in Europe | The level of ES implementation is still low (±20%) | Provides an overview of implementation barriers |
| 3 | Hamam Manal (15) | Circular Agro-Food System | Food systems need a circular model to reduce food waste. | Supporting the relevance of the Circular Economy in agriculture |
| 4 | Hongbin Cong (23) | Zero Waste City (China) | Processing organic waste into compost and energy | Provides a macro model of implementation |
| 5 | Vincent Savolainen (24) | Circular practices in Africa | Palm oil waste is used for food and feed | Shows opportunities for added value from by-products |

Source: ScienceDirect

Various factors play an important role in driving the development of circular economies across countries and industrial sectors (25). First, the limited availability of non-renewable natural resources raises awareness of the need for efficiency in their use and a reduced dependence on primary raw materials. Furthermore, the growing negative environmental impacts from extraction, manufacturing, and waste disposal activities create an urgent need for more sustainable solutions to reduce the ecological footprint. Another factor is the presence of supportive government regulations and policies, such as tax incentives for recycling, resource-efficiency standards, and waste management regulations that encourage industries to shift to environmentally friendly practices. On the other hand, technological advances in material processing, the development of alternative materials, and the use of information technology also open up significant opportunities to strengthen the implementation of circular economy principles.

The concept of a circular economy focuses on efficient resource use, waste reduction, and the regeneration of natural resources. The implementation of a circular economy can be classified into three levels: micro, meso, and macro (26).

a. The Micro Level implements an organization's specific efforts in reducing energy consumption, raw materials, and waste through the implementation of the 9R application (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover). This practice can be combined with an integrated farming system that synergistically combines elements of livestock, crop production, fish, poultry, trees, food crops, plantation crops, and

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other systems. The main objective of this principle is to produce new product designs oriented towards zero waste by emphasizing the reuse of resources throughout every production process.

b. The Meso level involves interactions between companies and across sectors in building collaborative networks focused on the supply chain and industrial ecosystem. At this level, the implementation of a circular economy can be achieved through the development of eco-industrial parks, where waste from one industry can be used as raw material for another (industrial symbiosis). Furthermore, companies can collaborate to create innovative circular business models, such as offering product-as-a-service, sharing platforms, and joint return and recycling systems, to increase efficiency and reduce environmental impact collectively.
c. The macro level extends from the national to global levels, where implementation depends on the role of governments, policymakers, and international institutions in driving the transformation towards a circular economy. These policies can include implementing strict regulations on waste management, providing fiscal incentives for environmentally friendly industries, establishing sustainability standards in production, and integrating circular economy principles into sustainable development strategies. At this level, successful implementation is also determined by community engagement through public education, promoting sustainable consumption, and developing supporting infrastructure such as recycling facilities and efficient logistics systems. Thus, the macro level serves as a strategic framework that guides systemic change towards a more resilient, inclusive, and sustainable economic model.

Apart from the concept, there are also important components in the circular economy (27), including:

a. Product design for long-term durability. Products are designed to be more durable, easy to repair, and reusable. Furthermore, hazardous materials are avoided, and materials are selected for easier recycling.
b. Optimizing resource utilization. Resource utilization focuses on high efficiency to reduce the need for new raw materials, including increased productivity, the use of renewable energy, and reductions in overall resource consumption.
c. Recycling and reuse. Used materials are reprocessed and reintroduced into the production chain, reducing reliance on primary raw materials.
d. Maintenance and repair. Products are designed for easy repair, extending their lifespan and reducing waste.
e. Closed-loop. Waste from one process can be reused as raw material for another process. This way, the need for new resources is minimized, and environmental impact is reduced.

**The Potential and Challenges of Implementing a Circular Economy in Indonesian Agriculture**

The agricultural sector in Indonesia currently still applies a traditional linear economic system which causes negative impacts on nature such as soil and water degradation and greenhouse gas production, so transformation and innovation must be carried out that support

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sustainable consumption and production and involve the community in recycling and must be facilitated by the government and the private sector to manage organic waste from agricultural production (28). A circular approach in Indonesia's agricultural sector holds significant potential by using agricultural waste as fertilizer and feed, improving input efficiency, and reducing methane emissions from organic waste. This is crucial because Indonesia has a very high level of food waste.

A circular economy in agriculture can be realized by converting agricultural waste into biochar and reintegrating it into the agricultural system (3). Biochar is a concrete example of the application of a circular economy in agriculture, namely the utilization of waste into value-added products that support sustainability. The application of biochar in agricultural practices can support nutrient recycling, reduce greenhouse gas emissions, and increase crop productivity, thus aligning with the main principles of a circular economy.

Within the framework of a circular economy, every product is seen as still having value after use, so it is important to reuse outputs previously considered waste to provide new functions (29). In the agricultural sector, this principle can be implemented through reducing the use of chemical pesticides that have the potential to pollute the environment, as well as processing agricultural waste and consumer food waste into compost that can then be reused as organic fertilizer. Implementing this strategy not only reduces production costs for farmers but also increases soil fertility, improves the structure of agricultural ecosystems, and reduces the potential for greenhouse gas emissions from the accumulation of organic waste in landfills (11). In accordance with point 12 of the Sustainable Development Goals (SDGs), namely, creating sustainable production and consumption.

The adoption of a circular economy in the agricultural sector still faces various obstacles, such as limited access to financing, inadequate infrastructure, weak extension services, and minimal business support services (30). In the context of integrated farming, challenges that arise include the relatively long time to see positive impacts, for example, increasing soil organic content, the need for interactive outreach between farmers and researchers or facilitators, and the need for increased expertise, funding, and technical support so that integrated farming systems can operate optimally and contribute to long-term economic and environmental sustainability (31). Other challenges that contribute to slowing the adoption of a circular economy are limited waste management infrastructure, low consumer awareness of the importance of sustainability, and minimal collaboration between stakeholders in supporting this transformation (32).

**Implementation Model Based on Literature Study**

Practical implementation of a circular economy involves strategies such as resource efficiency, waste reduction, and regenerative agriculture. More broadly, systematic reviews show that circular agricultural practices, such as agroforestry, composting, crop rotation, and the valorization of agricultural by-products, help close nutrient cycles and reduce dependence on external inputs. This aligns with the Sustainable Development Goals (SDGs) on responsible consumption and production. One implementation of this circular economy is integrated crop-

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livestock systems, which enable the use of crop waste as feed and livestock waste as fertilizer, increasing efficiency and environmental sustainability (33). The implementation of a circular economy across various countries is shown in Figure 2 below.

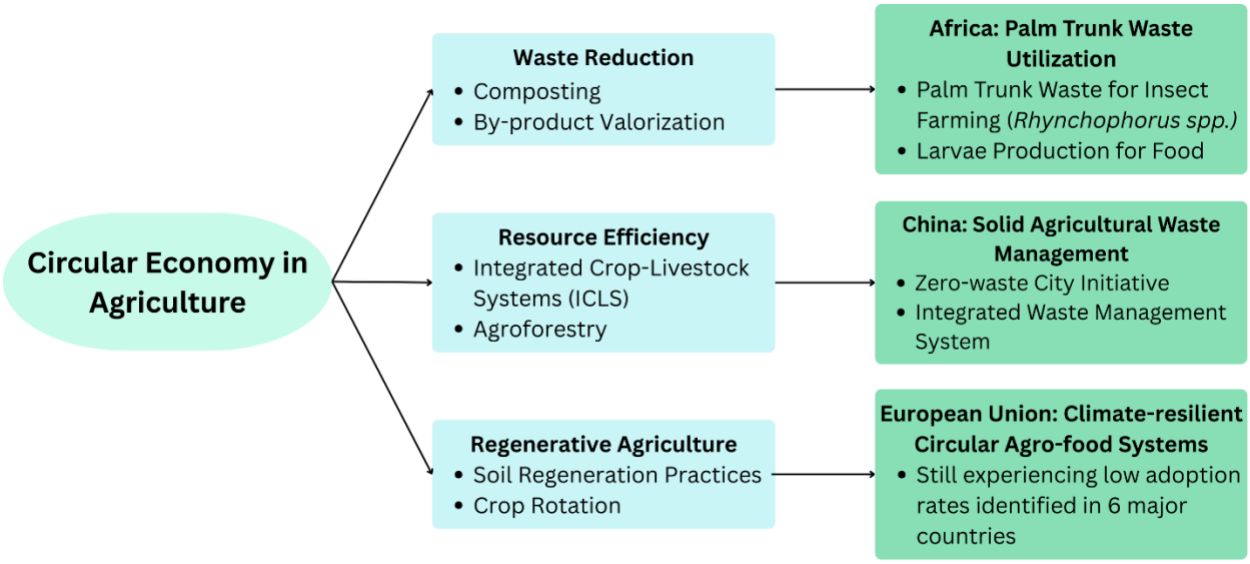


Figure 1. Implementation of a Circular Economy in Various Countries

Various implementation models have been demonstrated in international literature. African countries are implementing a circular economy for palm oil commodities by utilizing palm trunk waste as a cultivation medium for palm weevils (*Rhynchophorus spp*.), which produce protein-rich larvae for human consumption and animal feed (24). This practice not only adds economic value to agricultural waste but also creates a low-cost food source while increasing local incomes. The implementation of a circular economy in China is reflected in the government's focus on the management and utilization of agricultural and rural solid waste (23). One strategic step is the development of a "zero-waste city" concept to strengthen ecological civilization and create a sustainable environment. This concept not only encourages waste reduction but also opens new opportunities to implement a circular economy through co-processing and more diverse utilization of agricultural and rural waste.

The European Union and developed countries are promoting circular and sustainable agricultural practices to protect and improve environmental quality, ensuring the availability of nutrition for the community, maintaining climate stability, minimizing the impact of climate change on social life, strengthening the resilience and sustainability of agricultural production, and reducing dependence on external suppliers of raw materials and production inputs (34). A study shows that the level of implementation of the circular economy in the agro-food system in Europe is still low, especially in six central countries, namely France, Spain, Germany, Italy, the United Kingdom, and the Netherlands (11). Although these countries have significant potential for developing agro-food-based bioenergy, the conceptual and managerial understanding of circular economy implementation remains limited.

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**Strategic Recommendations for Implementing a Circular Economy in Sustainable Agriculture**

The circular economy model is an economic model that emphasizes optimizing the flow of resources through strategies for reusing, repairing, renewing, and recycling products and materials to maintain their economic value for as long as possible, thereby minimizing waste and maximizing the efficiency of resource utilization, as shown in Figure 3 regarding the concept of implementing a circular economy.

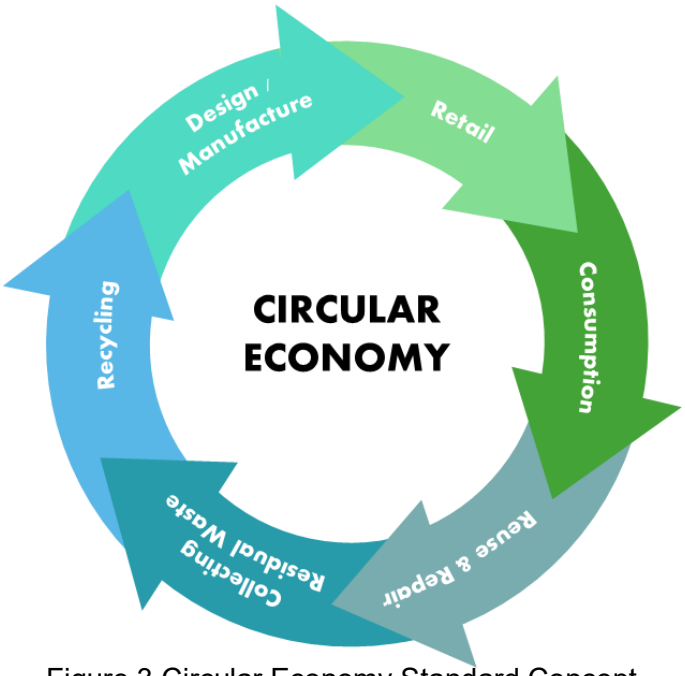


Figure 3 Circular Economy Standard Concept
Modified from (35,36)

Implementing a circular economy in the agricultural sector requires an integrated strategy among the government, the private sector, and the community (25). The government plays a crucial role by developing regulations that encourage agricultural waste management, the use of secondary raw materials, and the recovery of energy from production residues. Furthermore, fiscal incentive policies, such as subsidies and tax breaks for businesses that implement environmentally friendly practices, can drive the transition to a sustainable agricultural system. Further support can be provided through more selective public procurement mechanisms for circular principles-based products, thereby increasing market demand for green products. Furthermore, increasing public literacy regarding the importance of a circular economy must also be a priority (37). Educational programs, public campaigns, and technical training can help shift consumer mindsets and behavior toward more conscious consumption, such as promoting waste separation, reducing reliance on single-use products, and supporting the use of recycled products. Active community participation can be achieved through simple actions such as

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repairing agricultural equipment rather than throwing it away, using compost from organic waste, and supporting local markets that implement circular principles.

The research and innovation sector also plays a vital role in accelerating the implementation of a circular economy in agriculture (11). Investing in research into advanced waste management technologies, developing energy-efficient production processes, and promoting digital platforms based on the sharing economy can create new opportunities for more efficient resource use. At the same time, oversight and enforcement of laws against companies that fail to meet sustainability standards must be strengthened to ensure fairness in the transition to an environmentally friendly agricultural system. Finally, cross-sector collaboration is key to the successful implementation of a circular economy (38). Partnerships among government, the private sector, and civil society can strengthen the innovation ecosystem while providing concrete solutions better tailored to local needs. With a focused strategy and stakeholder involvement, implementing a circular economy can not only minimize negative environmental impacts but also create long-term economic benefits and ensure the sustainability of the agricultural sector for future generations.

## CONCLUSION

The application of a circular economy in the agricultural sector is a strategic approach to address the resource crisis, environmental degradation, and dependence on unsustainable linear systems. It is based on the principles of efficient resource utilization, waste reduction, and ecosystem regeneration, which can increase productivity, strengthen food security, reduce emissions, and create added value by turning waste into valuable products. However, its implementation in Indonesia still faces challenges, including limited financing, limited infrastructure, low literacy, and a lack of collaboration, and requires regulatory support, economic incentives, technology, and community participation. Based on international circular economy practices such as zero-waste cities in China, industrial symbiosis in Europe, and agricultural waste utilization in Africa, Indonesia has the potential to adapt a similar model through an integrated strategy across government, the private sector, academia, and civil society to achieve sustainable development, ecological balance, and long-term economic benefits. The findings of this study indicate that practically, a circular economy increases agribusiness efficiency, reduces costs, reduces dependence on external inputs, and strengthens food security, while theoretically enriching the study of sustainable agricultural development through the integration of circular economy principles at the micro, meso, and macro levels, so that the transformation towards a circular agricultural system requires strong regulations, increased farmer capacity, investment in appropriate technology, and multi-stakeholder collaboration to ensure a more adaptive, inclusive, and sustainable system.

## RECOMMENDATIONS

The main limitation of this study is the limited literature, which prevents broad generalization of the findings. This also highlights the need for more in-depth research into the specific challenges of implementing a circular economy in the Indonesian agricultural sector.

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Future researchers are advised to expand the scope of the literature and examine the results of circular economy implementation directly at the organizational, farmer group, or individual farmer levels to gain a more contextual understanding of the social, economic, and environmental implications. Furthermore, future researchers are expected to develop a circular economy implementation model that is more adaptable to local conditions, accounting for factors such as technology, human resource capacity, community consumption patterns, and regional policies. This will encourage collaboration between government, academics, and business actors to increase farmer capacity through training, technical assistance, and the provision of waste management infrastructure. Therefore, further research will not only enrich the theoretical foundation but also make a tangible contribution to formulating a more inclusive, applicable, and sustainable circular economy implementation strategy for the Indonesian agricultural sector.

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