Circular Economy in Agriculture: Integrating Technology for Sustainable Waste Management

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Abstract

The agricultural sector faces significant challenges due to increasing pressure on natural resources and the need for more sustainable production systems. The linear economic model that has dominated agricultural activities has led to high levels of waste and decreased resource efficiency. In this context, implementing a circular economy is a strategic step towards creating an efficient, environmentally friendly, and competitive agricultural system. This study aims to analyze how technology integration can strengthen the implementation of a circular economy in sustainable agricultural waste management. The study used a qualitative approach, collecting data from various sources, including previous research, policy reports, and scientific publications relevant to the theme of sustainable agriculture. The data obtained were then analyzed thematically to identify the relationship between technology implementation, policy, and multi-stakeholder collaboration in supporting a circular agricultural system. The results show that transforming agricultural systems toward resource efficiency requires strong support from digital technology, adaptive public policies, and active community participation in waste management. In addition to increasing farmer productivity and welfare, a circular system also strengthens local economic resilience and environmental sustainability. Therefore, technology integration in a circular agricultural economy is a crucial pillar for realizing modern agriculture that is equitable, inclusive, and long-term resilient.

Keywords: *Circular Economy, Agriculture, Waste Management.*

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A. INTRODUCTION

The global paradigm shift toward sustainable development has pushed the agricultural sector to adapt to increasingly complex environmental and resource efficiency challenges. In this context, the increasing volume of agricultural waste has become a critical issue threatening ecosystem sustainability and rural economic balance. For decades, conventional agricultural practices have tended to produce underutilized production waste, ranging from organic waste such as straw, husks, and livestock manure to inorganic waste from the use of agricultural chemicals (Karimi et al., 2021). This inefficiency in waste management not only causes ecological impacts such as soil and water pollution but also creates a high dependency on new natural resources. In this situation, an urgent need arises to restructure agricultural systems to be more adaptive to sustainability principles, where every byproduct of the production process can be reused as a new resource with economic value (Abubakar et al., 2022).

The transformation toward a more sustainable agricultural system cannot be separated from the role of technology as a key driver of change. Technological developments over the past two decades have presented significant opportunities for the agricultural sector to optimize every aspect of production, including waste management. Biomass processing technologies, smart sensor systems, digital platforms for supply chain monitoring, and data-driven applications for resource efficiency are all crucial catalysts for creating agriculture that is not only productive but also environmentally friendly (Khan et al., 2021). In various regions, the application of these technologies enables farmers and agribusinesses to convert agricultural waste into fuel, fertilizer, or new industrial raw materials. However, this enormous potential has not been fully exploited systematically, particularly in developing countries like Indonesia, where limited infrastructure, capital, and technological capacity often hinder the integration of innovation into local agricultural systems (Ufitikirezi et al., 2024).

On the other hand, the gap between technological progress and the socio-economic preparedness of agricultural communities remains a major challenge in building sustainable systems. Many agricultural areas still rely on traditional methods that pay little attention to energy efficiency and waste management. This situation results in a large portion of agricultural waste being simply dumped or burned, generating high carbon emissions and degrading the surrounding environment (Hariram et al., 2023). Amidst the growing demand for alternative energy and renewable raw materials, agricultural waste could potentially be a valuable resource. The transition to a smarter waste management system requires not only technology but also a shift in mindset and business models at the grassroots level. Cross-sector collaboration between government, academia, businesses, and farming communities is crucial to ensuring this transformation is effective (Clauser et al., 2021).

The global context also demonstrates that the issue of agricultural waste is no longer local but is interconnected with the dynamics of trade, climate, and global food security. Increased food production to meet the needs of a growing population places increasing pressure on natural resources and production systems. Without efficient waste management mechanisms, increased production will exacerbate environmental degradation and accelerate the decline in soil productivity (Wang et al., 2023). In many cases, countries with a high dependence on the agricultural sector face a dilemma between increasing crop yields and maintaining the sustainability of natural resources. Therefore, strategies that utilize agricultural waste to generate added economic value are highly relevant. The integration of technology into these systems serves not only as a tool but also as a transformative element, capable of shifting the perspective of waste from a useless item to a productive asset (He et al., 2024).

Beyond environmental aspects, sustainable agricultural waste management also has significant social and economic dimensions. In many rural areas, agricultural waste can provide additional income if processed properly. Innovations such as the production of biogas, organic fertilizer, or animal feed from waste can create new jobs and reduce dependence on imported agricultural inputs (Medici et al., 2021). However, this potential is often hampered by a lack of access to technology and inadequate training for farmers in managing more modern systems. Governments and research institutions have a strategic role to play in strengthening local capacity, providing incentives for technology adoption, and developing partnership models that bring together the public and private sectors to create a circular agricultural ecosystem (Vasavi et al., 2025).

Another challenge is the low awareness of the importance of integrating production and waste management systems within a sustainable economic framework. Many agricultural policies still focus on increasing production without considering the long-term impacts of the resulting residues. However, systems that ignore the circulation of resources create an imbalance between inputs and outputs, ultimately harming the agricultural sector (Hegab et al., 2023). In this context, technology-based approaches can provide accurate data and information to monitor material flows, detect potential waste, and optimize processing processes. Thus, the existence of digital systems and modern processing technology not only increases efficiency but also creates a monitoring and transparency mechanism in the management of agricultural resources (Du et al., 2024).

Furthermore, the application of sustainable principles in agricultural waste management is closely linked to national and global development agendas, such as food security, greenhouse gas emission reduction, and climate change adaptation. In Indonesia, the agricultural sector is the backbone of the economy, contributing significantly to employment and income for rural communities (Yu et al., 2025). However, this potential has not been matched by effective waste management that focuses on resource circulation. Many agricultural modernization programs still focus on the production and distribution of crops, while waste management remains a low priority. This highlights the need for new strategies that integrate technology throughout the agricultural value chain, from cultivation to waste management, to create a more resilient, efficient, and competitive system (Li & Guo, 2022).

Ultimately, the major challenge facing agriculture today is not only increasing yields but also creating production systems that minimize negative environmental footprints. Integrating technology into agricultural waste management is key to addressing this challenge. Through the implementation of innovations such as data-driven monitoring systems, biomass waste processing technology, and collaborative digital platforms, the agricultural sector has a significant opportunity to transform toward a more inclusive and sustainable economic model. With the right policy support, adequate research investment, and active engagement from the farming community, this model has the potential to become a key foundation for a greener and more efficient agricultural future. The transformation to a technology-based, circular agricultural system is not merely an option but an urgent necessity for future economic, social, and ecological sustainability.

B. LITERATURE REVIEW

A circular economy is an economic concept that aims to reduce the waste of natural resources and minimize waste by designing products to be recycled, reused, or recovered after use. The main principle of a circular economy is to shift consumption patterns from a linear model (take-make-dispose) to a more sustainable model, where products and materials remain in the economic cycle for as long as possible (Morseletto et al., 2022).

The circular economy began to gain popularity around the 1990s to address the challenges of economic development and reduce the excessive use of natural resources. The key points of a circular economy are to utilize manufactured goods and to balance economic growth with environmental and natural resource development (Corvellec et al., 2022).

In a circular economy, resource use, waste, emissions, and wasted energy are minimized by closing the production-consumption cycle through product life extensions, design innovation, maintenance, reuse, remanufacturing, recycling, and upcycling. In the context of plastic product sustainability, the circular economy concept can be applied in several ways, for example: recycling plastic, upcycling plastic as an asphalt mixture, converting low-value plastic into fuel or energy, and so on (Vogiantzi & Tserpes, 2023). The goal of a circular economy is to create a more environmentally and economically sustainable economic system by reducing dependence on limited natural resources and mitigating negative environmental impacts (Bianchi & Cordella, 2023).

A circular economy comprises three main principles: reducing waste and pollution, using products or materials sustainably, and renewing natural systems. This is based on the increasing use of renewable energy, accelerated by digital innovation. A circular economy is a resilient, distributive, diverse, and inclusive economic model. It embodies an economic concept that combines sustainable development and the implementation of a green economy (Yang et al., 2023).

The key principles of a circular economy can be grouped into several core concepts that cover various aspects, from product design to waste management. Here are some of the key principles of a circular economy:

1. Sustainable Product Design: Products are designed to have a longer lifespan, be easily recycled, or be repairable. This design minimizes waste and allows materials to be returned to the economic cycle.
2. Efficient Resource Utilization: Using natural resources wisely by reducing the consumption of primary raw materials and energy. This can be achieved by recycling materials, reusing products, or reducing material leakage in the production process.
3. Effective Waste Management: Reducing, recycling, and reusing waste to prevent waste accumulation and reduce environmental impact.
4. Exchange and Collaboration: Encouraging collaboration between companies, consumers, governments, and communities to create networks that support more efficient and sustainable material flows.

5. Technological and Business Innovation: Developing new technologies and business models that support circular economy principles, such as providing products-as-a-service or sharing platforms.
6. Education and Awareness: Raise awareness and education about the importance of a circular economy among the general public, industry, and other stakeholders (Burke et al., 2023).

These principles form a comprehensive framework for building a more sustainable economy, reducing our ecological footprint, and improving overall resource efficiency.

C. METHOD

This research will be conducted using a qualitative approach, aiming to deeply understand the dynamics of circular economy implementation in the agricultural sector through the integration of sustainable waste management technology. Through this approach, the research focuses not only on the final results but also on the processes, interactions, and social context surrounding the system's implementation in the field. Research data will be obtained from various relevant sources, such as previous research results, scientific publications, and empirical studies discussing sustainable agricultural practices and the application of environmental technology. Once all the data has been successfully collected, the next step is to systematically process and analyze it. The obtained data will be analyzed using thematic analysis techniques that allow researchers to identify patterns, trends, and relationships between technology implementation and the effectiveness of the circular economy system in agriculture. Each finding will be compared with previous research results to strengthen the validity and reliability of the analysis. This analysis process will produce a comprehensive picture of how technology can act as a catalyst in creating a waste management system that is not only environmentally friendly but also provides added economic value to the agricultural community. Thus, this research is expected to make scientific and practical contributions to the development of a sustainable agricultural model based on circular economy principles and technological innovation (Hasan et al., 2025).

D. RESULT AND DISCUSSION

1. Transforming Agricultural Systems Towards Resource Efficiency

Fundamental changes in agricultural systems are now moving toward achieving resource efficiency in response to the growing global challenges of food sustainability and environmental sustainability. The shift from traditional agricultural practices that tended to uncontrolled resource extraction to systems that emphasize efficiency and circularity marks a new era in how humans manage nature. Conventional approaches to agriculture have focused solely on increasing yields without considering ecosystem balance or sustainable land use. As a result, many byproducts, such as straw, rice husks, and other organic waste, are not optimally utilized and are often burned, causing pollution and losing economic potential. This shift toward resource efficiency has led to the emergence of a new paradigm that views every production residue as a valuable asset that can be returned to the productivity chain. This transformation requires not only technological innovation in production processes but also a renewed mindset among farmers and agribusinesses to view waste as an integral part of a sustainable agricultural economic cycle (Rathour et al., 2023).

Within the context of this paradigm shift, strategies for optimizing production inputs are crucial to reducing dependence on increasingly limited natural resources. The use of water, energy, and fertilizers must be managed in such a way that they are efficient and sustainable. In many agricultural areas, water use is often carried out without careful calculation, resulting in waste and soil degradation. Through smart irrigation systems and the use of technology-based weather data, water needs can be predicted and adjusted to crop conditions. Similarly, energy use in agriculture can now be optimized through the application of renewable energy sources, such as biogas produced from organic agricultural waste, eliminating complete reliance on fossil fuels. On the other hand, the excessive use of chemical fertilizers has long been a serious problem, reducing soil fertility and damaging microbial ecosystems. Therefore, developing organic fertilizers from processed agricultural waste is a strategic step in creating a production system that is not only efficient but also strengthens the natural cycle of soil fertility.

Increasing farmers' capacity to manage crop residues into productive materials is a crucial component in the transformation of a modern agricultural system. Limited knowledge and access to technology often prevent farmers from processing crop byproducts into economically valuable products. Through ongoing training, extension, and mentoring, farmers can learn how to convert agricultural waste into new materials, such as animal feed, compost, or bioenergy. This capacity building not only increases resource efficiency but also creates new economic opportunities for rural communities. Farmers who effectively process agricultural waste can reduce production costs and generate additional income from these products. Furthermore, the involvement of younger generations in the agricultural modernization process is crucial to accelerating this transformation. With broader insights into technology and innovation, they can introduce production systems that adapt to climate challenges and global market changes, thereby strengthening the competitiveness of the national agricultural sector.

The transformation towards resource efficiency also requires the integration of the entire agricultural value chain, from production to distribution. In a fragmented system, much agricultural produce is wasted due to under-utilization or damage during transportation and storage. Value chain integration enables all components of the agricultural system to work in sync, ensuring no waste and that any remaining production can be reused in different cycles. This is where logistics and distribution play a key role. The use of digital technology in supply chain management enables farmers, processors, and distributors to monitor material flows in real time, estimate market demand, and adjust harvest and distribution times to align with demand. Cold storage systems, efficient transportation, and robust market infrastructure are supporting factors in achieving this efficiency. Through strong integration, agriculture becomes not only a production activity but also an adaptive, resilient economic system with minimal value loss at every stage of the supply chain.

The shift towards a more efficient agricultural system in resource utilization has far-reaching impacts that extend beyond production to encompass the social and economic aspects of rural life. When every resource is optimally managed and waste is processed into value-added products, the well-being of rural communities significantly improves. This approach opens up new opportunities in various sectors, from waste management and renewable energy development to the growth of agricultural-based creative industries. Through this diversification, rural economies become more dynamic and no longer solely dependent on primary crops. Furthermore, efficiency in resource utilization strengthens the resilience of agricultural systems to external pressures such as rising input prices, climate change, and disruptions to global supply chains. With an integrated and adaptive system, the agricultural sector can maintain sustainable productivity while enhancing long-term economic independence for communities.

Efforts towards a resource-efficient agricultural system are now a strategic step in maintaining the sector's sustainability amidst increasing pressure on global land and energy availability. Innovations implemented across various sectors are focused not only on increasing productivity but also on creating a balance between economic growth and environmental preservation. Approaches such as wise waste management, renewable energy use, farmer capacity building, and value chain integration are key pillars in building a resilient and competitive agricultural ecosystem. Through close collaboration between the government, academics, businesses, and the community, the trend toward resource efficiency is transforming into a concrete movement that supports sustainable agriculture. Thus, this sector is not only able to address food security challenges but also plays a role in addressing the global environmental crisis.

2. The Role of Technology in Optimizing Agricultural Waste Management

Technological advances play a crucial role in driving the optimization of agricultural waste management as part of efforts towards a more efficient, productive, and sustainable agricultural system. Amidst increasing pressure on natural resources and the need to minimize environmental impact, the application of technology bridges the gap between production efficiency and ecological responsibility. Waste management, once conventional, has now transformed into a data-driven, sensor-driven, and automated system. With the support of these technological devices, farmers can detect, monitor, and manage production waste in real time. Sensors integrated into agricultural fields provide information on soil moisture, nutrient content, and the volume of organic waste produced. Accurate and regularly updated data enables faster and more precise decision-making, reducing the potential for waste and environmental pollution. Internet of Things (IoT)-based technology and digital monitoring systems also strengthen the agricultural sector's ability to operate predictively, enabling waste processing to begin before it has a broader negative impact on the ecosystem.

Utilizing technology to process organic waste into new materials such as fertilizer, animal feed, or alternative energy is one of the most strategic steps in realizing sustainable agriculture. Agricultural waste, once considered a burden, can now be converted into a new resource with high economic value. Through biotechnology-based processing systems, such as fermentation and microbial decomposition, organic waste can be transformed into high-quality compost that can improve soil structure and increase crop productivity (Xu et al., 2023). Meanwhile, biodigester technology enables the conversion of organic waste into biogas, which can be used as a renewable energy source for agricultural activities, such as powering water pumps, agricultural machinery, or even lighting in rural areas. Furthermore, byproducts of this process, such as solid residues, can be used as raw materials for organic fertilizers, creating a circular system with virtually no waste. This process not only reduces dependence on chemical fertilizers and fossil fuels but also supports the transition to a green economy oriented towards resource efficiency.

In addition to processing technology, digitalization plays a central role in monitoring the flow of waste materials and improving the efficiency of agricultural supply chains. With an integrated digital system, every stage of the production process, from production to waste processing, can be tracked and managed more transparently. Digital platforms enable farmers, waste processors, and distributors to connect within a unified data ecosystem. Through cloud-based monitoring applications, for example, information on waste volume, collection locations, and processing times can be quickly obtained, minimizing the risk of delays and loss of valuable materials. This digitalization also simplifies data analysis to identify patterns and trends in waste production, which can then be used to improve the efficiency of future production processes. Furthermore, blockchain technology is beginning to be used in several supply chain systems to ensure transparency and accountability in waste management, while also providing incentives for actors committed to sustainable agricultural practices.

However, the optimal application of technology in agricultural waste management cannot be achieved without strong collaboration between technology innovators and agricultural stakeholders. This collaboration is a crucial foundation for accelerating the adoption of innovations in the field. Technology developers need to understand the social, economic, and ecological conditions faced by farmers so that their products truly meet the needs of the field. Conversely, farmers also need support with training and mentoring to understand how new technologies work and the benefits they generate from their implementation. The involvement of research institutions, universities, and the government also plays a crucial role in bridging the gap between innovation and implementation. By creating an inclusive collaboration model, technology adoption can be gradual and sustainable, resulting in a tangible impact on increasing the efficiency of agricultural waste management systems. This collaboration also opens up opportunities for innovations based on local experiences and practices, making the technology more adaptable to the social and geographic context of each agricultural region.

Despite the enormous potential of technology in agricultural waste management, its implementation in the field is not without various technical and social challenges. In many rural areas, limited digital infrastructure is a major obstacle to implementing data- and sensor-based systems. Access to modern technology is often hampered by cost, limited internet connectivity, and a lack of technical expertise among farmers. Furthermore, social resistance to change persists, particularly among farmers accustomed to conventional methods and reluctant to switch to new, more complex systems. Another challenge lies in the capacity gap between developed and underdeveloped regions, where the ability to adopt and maintain technology still varies widely. To address this, policies that support equitable access to agricultural technology and sustainable mentoring strategies are needed so that the digitalization and modernization process not only benefits certain groups but truly creates broad benefits for all actors in the agricultural sector.

3. Social and Economic Impacts of Implementing Circular Farming Systems

The implementation of a circular agricultural system has had a significant impact on the social and economic changes in rural communities. This shift is evident in how farmers have begun to utilize agricultural byproducts or waste as economically valuable resources, thus opening up previously unimaginable additional income opportunities. Waste such as straw, fruit peels, livestock manure, and organic residues are no longer considered production waste, but rather potential raw materials to be processed into new commodities such as organic fertilizer, biogas, or animal feed (Mulya et al., 2025). This process not only increases farmers' incomes but also creates stronger economic independence at the local level because existing village resources can be reused repeatedly without relying on external supplies. Thus, the circular system strengthens the economic resilience of farming communities against market price fluctuations and natural resource crises that often threaten the conventional agricultural sector.

Furthermore, the implementation of this system has also encouraged the creation of new and diverse jobs in the fields of waste processing and derivative product innovation. The emergence of small businesses engaged in the recycling of agricultural materials or the production of alternative biomass-based energy, for example, is concrete evidence of how the rural economy can grow inclusively through circular mechanisms. Economic activities focused on adding value to waste also provide employment opportunities for community groups previously less involved in the direct agricultural sector, such as women and rural youth. This social transformation demonstrates that circular agriculture not only strengthens the economy but also promotes more equitable social empowerment. Furthermore, collective activities in managing agricultural waste foster social solidarity and collaboration among farmers, ultimately strengthening social cohesion and creating networks that are more adaptive to environmental and market changes.

From a local economic perspective, circular farming systems create a more efficient and self-sufficient resource cycle. When organic materials generated from production waste can be returned to the value chain in the form of energy or fertilizer, agricultural operational costs are reduced, while land productivity increases. This pattern reduces community dependence on imported agricultural inputs and simultaneously strengthens local economic resilience. The result is a more resilient and sustainability-oriented village economy, where every resource is optimally utilized without wasting it. Over time, this approach can increase the competitiveness of rural areas due to production systems that are energy-efficient, low-emission, and adaptive to climate change.

Beyond economic impacts, the implementation of circular farming systems also has strong social implications, transforming community behavior. Increased awareness of the importance of waste management and environmentally friendly production practices has transformed farmers' perspectives on natural resources. This awareness reinforces values of sustainability and ecological responsibility within farming communities, where practices such as waste separation, the use of organic fertilizers, and the utilization of renewable energy are becoming part of daily habits. These behavioral changes not only improve the quality of the local environment but also provide long-term benefits in the form of improved quality of life and community health.

Ultimately, circular agricultural systems contribute to the development of more sustainable consumption and production patterns. By integrating the principles of resource efficiency and technological innovation, rural communities are beginning to build more resilient food systems oriented toward long-term sustainability. Local products resulting from recycling or waste processing have competitive market value and are environmentally friendly, strengthening the position of the rural economy in regional and national supply chains. In the long term, this system not only strengthens the village economy but also plays a crucial role in maintaining ecological and social balance in rural areas, making circular agriculture a strategic foundation for holistic sustainability.

4. Policy Strategy and Multi-Stakeholder Collaboration to Promote Sustainable Agriculture

The implementation of a circular economy system in the agricultural sector cannot be effective without a targeted policy strategy and strong multi-stakeholder collaboration. The government has a central role in building a regulatory foundation capable of encouraging technological innovation, resource efficiency, and integrated waste management. Public policies that support the development of green technology, incentivize sustainable agricultural practices, and establish clear waste management regulations are key to accelerating the transition to a circular system (Poponi et al., 2021). Through an adaptive regulatory approach, the government can create an innovation ecosystem that enables agricultural actors to adopt new technologies without excessive administrative burdens. Furthermore, policies that emphasize the importance of education and training for farmers in organic waste management can be a crucial instrument to ensure that the transformation to sustainable agriculture occurs not only at the policy level but also in real-world practice.

Private sector involvement also plays a crucial role in strengthening the circular agricultural system. Companies engaged in technology, logistics, or agricultural production can be key drivers in creating more efficient supply chains based on recycling principles. Through strategic partnerships, the private sector can provide the technological infrastructure needed by farmers to process waste into value-added products, such as bioplastics, organic fertilizers, or biomass energy. Furthermore, private sector investment in research and development (R&D) can accelerate the development of innovations tailored to local needs. Agribusinesses that implement sustainable business models also have the potential to expand markets for environmentally friendly products from farming communities, creating mutually beneficial economic synergies. In this context, collaboration between the government and the private sector can create agricultural systems that are not only economically efficient but also positively impact the environment and social well-being.

Research institutions and universities play a crucial role as bridges between science and practice. The development of applied technologies such as biotechnology-based waste treatment systems, digital land monitoring applications, and renewable energy innovations from agricultural residues is an important contribution from academia to sustainable agriculture. Through interdisciplinary research, academic institutions can generate contextual solutions tailored to agroecological and social conditions in various regions. In addition to producing technology, universities also play a role in developing human resources competent in managing circular systems holistically. Research partnerships between universities, local governments, and industry players can accelerate the diffusion of technology into society while ensuring that the resulting innovations are truly applicable and sustainable.

Furthermore, collaboration with local communities is a key element in ensuring the successful implementation of a circular economy system in agriculture. Direct community involvement in waste management programs, training in organic fertilizer production, or the formation of green cooperatives can strengthen sustainable practices at the grassroots level. Local communities serve not only as beneficiaries but also as key drivers in maintaining the system's sustainability. Through a participatory approach, every individual in the community has a sense of ownership in the agricultural transformation process, so that the implementation of circular principles doesn't stop at short-term projects but becomes part of the community's production and consumption culture. Support from civil society organizations and non-governmental organizations (NGOs) can also help bridge the gap between policy and implementation, particularly in the context of capacity building, outreach, and village community education.

However, the success of this multi-stakeholder policy strategy and collaboration faces several challenges, both institutionally and in terms of intersectoral coordination. One major obstacle is the suboptimal integration between government agencies in managing cross-sectoral policies covering agriculture, the environment, energy, and trade. Policy fragmentation often leads to overlapping programs and weak implementation at the local level. Therefore, a solid coordination mechanism and an integrated monitoring system are needed to ensure that implemented policies truly support the long-term goals of circular agriculture. A collaborative approach involving all stakeholders equally can be a solution to overcome these obstacles. With strong synergy between the government, the private sector, academic institutions, and communities, a sustainable agricultural system based on a circular economy can develop into a development model that not only strengthens national food security but also maintains ecological balance and social justice in rural areas.

E. CONCLUSION

The application of a circular economy in the agricultural sector shows significant potential for creating a more efficient, sustainable, and value-added production system. The transformation to a circular agricultural system requires a fundamental shift in the production paradigm, where every resource is optimally utilized, and production by-products are no longer considered waste but rather as recyclable materials to support subsequent agricultural processes. Through technology integration, the efficiency of water, energy, and fertilizer use can be improved, while agricultural waste management can be carried out in real-time and measurable ways. As a result, agriculture becomes not only more productive but also more environmentally friendly and supports long-term food security. The social and economic impacts of implementing a circular agricultural system have proven significant, particularly in improving the welfare of rural communities. By utilizing waste as a new source of income, creating jobs in innovation and processing of derivative products, and increasing public awareness of the importance of sustainable production, this system strengthens the foundation of a resilient and independent local economy. However, its successful implementation requires appropriate policy support and strong cross-sector collaboration. The government, the private sector, research institutions, and communities must work together to build an inclusive, innovative, and sustainability-oriented agricultural ecosystem. With targeted policy strategies, effective multi-stakeholder collaboration, and the use of appropriate technology, circular farming systems can become a key pillar of future agricultural development. This approach not only strengthens national economic competitiveness but also maintains ecological and social balance in rural areas. Ultimately, technology-based circular agriculture is a pathway to a more equitable, adaptive, and sustainable food system transformation, while also making a tangible contribution to Indonesia's green development agenda.

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