



# Agrocomplex Transformation Towards Circular Economy Opportunities and Challenges of Implementation in Indonesia

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## Abstract

This study critically examines the transformative potential of circular economy principles within Indonesia's agrocomplex sector, an imperative shift given the agricultural sector's 13% contribution to the national GDP and employment of 29% of the workforce. Through a mixed-method approach incorporating in-depth interviews with 35 key stakeholders across five major Indonesian regions, focus group discussions, and system dynamics modeling, the research identifies significant opportunities for resource optimization where 63.7% of agricultural biomass currently remains unutilized or burned. The study uncovers five promising circular business models: Industrial-Agricultural Symbiosis, Agricultural Resource Sharing Platforms, Distributed Biorefinery, Product-as-a-Service Agriculture, and Regenerative Supply Chains, with Industrial-Agricultural Symbiosis demonstrating the highest benefit-cost ratio of 3.7 and potential carbon emission reductions of 42%. Key implementation enablers include supportive policies, access to green financing, technological capacity, multi-stakeholder collaboration, and capacity development, while primary barriers encompass value chain fragmentation, infrastructure limitations, inadequate economic incentives, resistance to change, and capacity constraints. A strategic three-phase roadmap (2025-2035) is proposed to accelerate the transition toward a circular agrocomplex in Indonesia, requiring an estimated investment of Rp156.3 trillion over a decade with potential to create 4.4 million new jobs. The findings emphasize the importance of integrating traditional agricultural wisdom with modern technology and establishing collaborative governance frameworks to ensure an equitable distribution of benefits throughout the agricultural value chain, ultimately redefining the relationship between production, consumption, and regeneration in Indonesia's food system.

**Keywords:** Circular Economy , Agrocomplex, Sustainable Agriculture, Industrial-Agricultural Symbiosis, Value Chain Integration, Biomass Utilization

## 1. Introduction

Indonesia as an agricultural country faces complex challenges in its efforts to synergize economic development with environmental sustainability. The agricultural sector, which contributes around 13% of Indonesia's total Gross Domestic Product (GDP) and employs more than 29% of the workforce [1], is now at a transformative crossroads towards a more sustainable

paradigm. The pressures of population growth, limited productive land, environmental degradation, and climate change are forcing the agrocomplex sector to adapt to a more regenerative and efficient economic model in resource utilization.

The circular economy is presented as an alternative paradigm to the conventional linear economic model with a "take-produce-dispose" pattern. The circular approach emphasizes the design of systems that minimize waste through the reuse, recycling, and regeneration of biological and technical materials in a closed cycle [2]. In the context of agrocomplexes, the application of circular economy principles has the potential to create significant added value through the utilization of agricultural waste, reduction of external inputs, and restoration of degraded natural capital.

In Indonesia, the transformation towards circular agrocomplexes has a special urgency given the unique geographical, social and ecological context. As the world's largest archipelagic country with extraordinary biodiversity, Indonesia has great potential to develop circular agrocomplex models that have positive economic, social and environmental impacts. Recent studies have shown that implementing a circular economy in Indonesia's agricultural sector could reduce greenhouse gas emissions by 26% and create 4.4 million new jobs by 2030 [3]. However, this transition cannot be separated from the structural challenges faced, including fragmentation of value chains, limited infrastructure and gaps in coherent policies.

The implementation of a circular economy in Indonesian agrocomplexes requires a systems approach that takes into account the complexity of interactions between various stakeholders, including small-scale farmers, agro-industry, consumers, and policy makers. Pratiwi and Suzuki (2023) emphasize the importance of a collaborative approach involving all actors in the agricultural value chain to achieve an inclusive and equitable transition [4]. In addition, the integration of innovative technologies such as the Internet of Things (IoT), artificial intelligence, and biotechnology has the potential to accelerate the transformation of agrocomplexes towards a more circular and regenerative model.

This article aims to explore the opportunities and challenges of the transformation of Indonesia's agrocomplex towards a circular economy paradigm. By mapping the existing agrocomplex ecosystem, identifying potential circular practices, and analyzing implementation barriers, this article is expected to contribute to the development of a strategic framework for accelerating the transition towards a competitive and sustainable circular agrocomplex in Indonesia.

## 2. Analysis of Methods

This study adopted a mixed-method approach integrating quantitative and qualitative analysis to explore the potential and challenges of transforming Indonesia's agrocomplexes towards a circular economy model. Primary data were collected through a series of in-depth interviews with 35 key stakeholders including farmers, agro-industry players, academics, policy makers, and non-governmental organizations in five major agrocomplex regions of Indonesia (Java, Sumatra, Kalimantan, Sulawesi, and Bali-Nusa Tenggara). The interviews focused on stakeholders' perceptions, experiences, and perspectives on the implementation of circular economy practices in the agrocomplex context. In addition, three focus group discussions were conducted to validate initial findings and develop contextual policy recommendations. Secondary data were obtained from national statistical databases, policy reports, and relevant scientific



literature for comparative and contextual analysis.

Data analysis used a system dynamics modeling approach to identify critical factors influencing the transition to circular agrocomplexes, including leverage points, barriers, and potential interventions. The Analytical Hierarchy Process (AHP) method was applied to prioritize policy interventions based on criteria of economic feasibility, environmental impact, social acceptability, and institutional fit. Internal validity of the study was ensured through triangulation of data sources, methods, and analysis, while external validity was strengthened through verification of findings with experts and practitioners of the circular economy. As a theoretical basis, this study adopted the multi-level perspective (MLP) framework developed by Geels [5] to understand the dynamics of socio-technical transitions in the context of Indonesian agrocomplexes.

### 3. Results

#### Status Quo and Potential of Circular Economy in Indonesian Agrocomplex

The analysis results show that circular economy practices in the Indonesian agrocomplex sector are still in their early stages with varying levels of penetration across subsectors and geographic regions. Based on a comprehensive mapping of material and energy flows in the agrocomplex value chain, it was identified that 63.7% of agricultural biomass that has the potential to be reused is currently wasted or burned, especially in areas with limited infrastructure such as eastern Indonesia [6]. This finding underscores the significant opportunities for optimizing biological resources through a circular approach. Case studies on five strategic commodities (rice, palm oil, sugar cane, corn, and cocoa) show the potential for additional economic value of IDR 47.3 trillion per year if agricultural waste from the five commodities is optimally utilized in bioenergy applications, animal feed, biopesticides, and sustainable building materials.

Stakeholder perception analysis revealed a gap in understanding and awareness of the circular economy concept among agro-complex actors. Although 82% of respondents from agro-industry and academia indicated a good understanding of the concept, only 31% of small-scale farmers were familiar with the principles of the circular economy. This knowledge gap strongly correlated with the adoption rate of circular practices at the field level, where 73% of identified circular practices were initiated by medium-large agro-industries, while small-scale actors tended to continue implementing conventional linear practices. These findings highlight the importance of a more inclusive and transformative approach in the dissemination of circular economy concepts and practices across the agro-complex value chain.

#### Potential Circular Business Models for Indonesian Agrocomplexes

Based on technical and economic feasibility analysis, this study identified five circular business models that have high potential to be applied in the context of the Indonesian agrocomplex: (1) Industrial-Agricultural Symbiosis, (2) Agricultural Resource Sharing Platform, (3) Distributed Biorefinery, (4) Agricultural Services Instead of Products, and (5) Regenerative Supply



Chain. The Industrial-Agricultural Symbiosis model that integrates waste streams from various productive sectors shows the highest level of economic feasibility with a benefit-cost ratio of 3.7 and a potential reduction in carbon emissions of up to 42% compared to conventional practices [7]. A case study in the Subang Integrated Industrial Area, West Java, proves the success of this model in creating additional economic value of IDR 12.5 billion per year from the transformation of 8,500 tons of organic waste into value-added products.

While all five business models show promising potential, their implementation faces varying challenges. The Agricultural Resource Sharing Platform model, for example, faces obstacles in the form of low levels of digital technology penetration among smallholder farmers, while the Distributed Biorefinery model is constrained by limited investment and infrastructure in rural areas. The technology gap analysis identified an investment requirement of IDR 82.7 trillion in biomass transformation infrastructure, integrated logistics systems, and data management technologies along the value chain to realize the full potential of these circular business models.

### **Enablers and Barriers to Circular Economy Implementation**

The analysis results identified five key enablers that play a significant role in accelerating the transition towards circular agrocomplexes in Indonesia: (1) Supportive policies and regulations, (2) Access to green finance and investment, (3) Technology and innovation capacity, (4) Multi-stakeholder collaboration, and (5) Education and capacity development. Among these five factors, supportive policies and regulations are the most critical lever with a weight of 0.28 in the AHP analysis. This finding is reinforced by case studies in four ASEAN countries (Thailand, Vietnam, Malaysia, and the Philippines) which show a significant positive correlation ( $r=0.76$ ,  $p<0.01$ ) between the maturity of the circular economy policy framework and the level of adoption of circular practices in the agricultural sector.

Meanwhile, the five key barriers in the transformation of agrocomplexes towards a circular economy include: (1) Fragmentation of value chains and information, (2) Limited supporting infrastructure, (3) Inadequate economic incentives, (4) Resistance to change, and (5) Limited capacity and skills. Value chain fragmentation emerged as the most significant barrier with 87% of respondents from all stakeholder categories citing it as the main obstacle. Social Network Analysis of the flow of information and resources in the rice commodity value chain in Central Java confirmed the high fragmentation with a network density index of only 0.34 on a scale of 0-1, far below the threshold of 0.6 required for effective coordination in implementing the circular model [8].

### **Strategic Roadmap for Transition Towards Circular Agrocomplex**

Based on the synthesis of quantitative and qualitative findings, this study develops a strategic roadmap for accelerating the transition towards circular agrocomplexes in Indonesia. The roadmap consists of three phases: (1) Initiation Phase (2025-2027) which focuses on developing a policy framework, raising awareness, and establishing pilot projects; (2) Acceleration Phase (2028-2032) which emphasizes infrastructure development, capacity building, and expanding the scale of implementation; and (3) Institutionalization Phase (2033-2035) which aims to realize systemic transformation and full integration of circular principles in the national agrocomplex.

Priority interventions in the initiation phase include: (1) Development of fiscal policies that support investment in circular technology and infrastructure, (2) Strengthening inter-sector partnership platforms to improve the flow of information and resources, (3) Investment in pilot



projects in 10 strategic agribusiness centers, (4) Development of standardized measurement and reporting systems, and (5) Strengthening circular economy education and literacy programs for agrocomplex actors. The estimated investment requirement for the implementation of this roadmap reaches IDR 156.3 trillion over a 10-year period, with the potential for significant contributions to the national carbon emission reduction target and the creation of 4.4 million new jobs in the agrocomplex sector and related industries.

#### 4. Discussion

Although research findings reveal relatively low adoption rates of circular economy at the smallholder level, it is important to note that many traditional Indonesian agricultural practices have in fact inherently implemented circularity principles. Practices such as the subak system in Bali, intercropping in Java, and agroforestry in Kalimantan reflect local wisdom philosophies of cyclical and regenerative resource use [9]. However, these practices are often not recognized as manifestations of circular economy due to the dichotomy between local knowledge and modern scientific discourse.

Systematic integration of local knowledge and modern technology can be a powerful catalyst for accelerating the transition towards circular agrocomplexes. In contrast to the findings of Wijaya et al. [3] who tend to emphasize the role of cutting-edge technology, the results of this study show that a hybrid model that combines traditional wisdom with technological innovation has a much higher level of social acceptance (acceptance score of 4.2 / 5 compared to 2.8/5 for the pure technology approach). This approach also has advantages in terms of resilience to external shocks, as evidenced by the case of regenerative agriculture in Boyolali Regency which was able to survive extreme climate conditions in 2022-2023 with a productivity decline of only 8.7% compared to 31.2% in conventional farming systems.

Analysis of the policy landscape related to the circular economy in Indonesia shows regulatory fragmentation and incoherence between sectors that hinder full-scale implementation. Although Indonesia already has several supporting policies such as Presidential Regulation No. 18/2020 on the National Medium-Term Development Plan which mentions the circular economy and Law No. 22/2019 on Sustainable Agricultural Cultivation Systems, harmonization of cross-sectoral policies remains a major challenge.

In contrast to the top-down approach often advocated in the literature [10], this study proposes a collaborative governance model involving multi-level policy orchestration. This model emphasizes the importance of shifting from a prescriptive policy framework to an adaptive framework that can respond to complex dynamics in agro-complex socio-technical systems. Policy experimentation through special regulatory zones can be an effective instrument to bridge the gap between policy narratives and implementation on the ground. A case study in Banyuwangi Regency that implemented an adaptive regulatory approach showed a 47% increase in the adoption of circular practices by smallholder farmers compared to areas with a conventional regulatory approach.

The transition to a circular economy is not merely a technical-economic issue, but also involves profound social transformation. The research results reveal the potential for redistribution of power and economic value in the agro-complex chain as a consequence of the implementation of circular business models. Socio-economic network analysis shows that the



Industrial-Agricultural Symbiosis and Resource Sharing Platform models have the potential to shift the balance of power from dominant actors (such as wholesalers and agro-industries) to primary producer communities, especially when implemented through collective mechanisms such as cooperatives and farmer groups.

However, the findings also indicate the risk that without appropriate interventions, circular economy adoption could widen existing socio-economic disparities. Data from early implementation of the Distributed Biorefinery model shows that 68% of the value added from biomass transformation tends to be concentrated among actors with investment and technological capacity, while smallholders receive only 12% of the value added. To anticipate these distributional impacts, the circular economy implementation framework needs to explicitly integrate just transition principles that ensure inclusive participation and fair distribution of benefits across the value chain.

This study faces several methodological limitations that need to be acknowledged. First, although the study sample covers five major regions, the very high heterogeneity of Indonesia's agrocomplex limits the generalizability of the findings. Second, the temporal dimension of socio-technical transformation has not been fully captured in the cross-sectional research design used. Third, the economic analysis conducted has not fully taken into account environmental externalities in calculating the feasibility of the business model.

Future research should expand the scope of analysis with longitudinal designs to understand the dynamics of the transition in the long term. Cross-regional comparative studies are also needed to identify common patterns and contextual variations in circular economy implementation. In addition, the integration of ecosystem valuation and natural resource accounting methods in economic analysis can provide a more comprehensive picture of the true value of circular agrocomplex models. The development of standardized indicators and metrics to evaluate “circularity” in the agrocomplex context is also a promising research area **to support evidence-based monitoring and evaluation of policies.**

## 5. Conclusion

This study explores the opportunities and challenges of transforming Indonesian agrocomplexes towards a circular economy paradigm through a comprehensive mixed-methodological approach. Key findings suggest that although the implementation of circular practices in Indonesian agrocomplexes is still at an early stage, there is significant potential for bioresource optimization, carbon emission reduction, and additional economic value creation through circular approaches. The five identified circular business models—Industrial-Agricultural Symbiosis, Agricultural Resource Sharing Platform, Distributed Biorefinery, Agricultural Services Rather Than Products, and Regenerative Supply Chains—offer an operational framework for implementing circular economy principles in the context of Indonesian agrocomplexes.

Accelerating the transition towards a circular agrocomplex requires a systems approach that integrates interventions at various levels, starting from strengthening a coherent policy framework, developing supporting infrastructure, facilitating access to finance and technology, to strengthening the capacity and awareness of agrocomplex actors. The proposed three-phase roadmap offers a strategic framework for orchestrating these interventions in a structured and sustainable manner. Most importantly, this transformative approach needs to take into account





the dimensions of social justice and inclusivity to ensure that the benefits of the transition towards a circular economy are distributed fairly across the agrocomplex value chain.

Despite the challenges in implementation, the integration of circular economy principles in Indonesian agrocomplexes has the potential to simultaneously catalyze economic growth, improve social welfare, and restore the ecological integrity of food systems. In this context, the circular economy is not merely a technical approach to resource efficiency, but a transformative paradigm that can redefine the relationship between production, consumption, and regeneration in sustainable agrocomplex systems.

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