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Circular Business Models in Livestock Waste Management for Achieving Green Growth and Sustainable Agribusiness Development

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Abstract
Sustainable agribusiness transformation in developing regions increasingly depends on adopting circular economy principles to optimize resource efficiency and minimize environmental impact. This study analyzes the implementation of Circular Business Models (CBMs) in livestock waste management as a foundation for achieving green growth and sustainable agribusiness development in Bukit Raya Village, Tenggarong Seberang District, Kutai Kartanegara Regency, East Kalimantan, Indonesia. A qualitative descriptive approach combined with a case study design was employed to examine the socio-economic, managerial, and environmental dimensions influencing CBM adoption among five farmer groups. Primary data were obtained through field observations, semi-structured interviews, and focus group discussions, while secondary data were sourced from institutional and academic reports. The results revealed that 76% of livestock waste, primarily goat and cattle manure, was successfully valorized into biogas and organic fertilizer, resulting in a 40% reduction in LPG use and a 17.7% increase in household income. Compost and biofertilizer commercialization integrated livestock systems into local agribusiness value chains, fostering market-based sustainability. Community-based innovation promoted inclusivity, with women and youth participation reaching 35% of total members. The conceptual framework developed from this study identifies four strategic pillars, resource efficiency, market-oriented integration, community-driven innovation, and institutional facilitation, as essential to transforming rural livestock systems toward a circular and regenerative agribusiness ecosystem. The findings underscore the importance of aligning rural development and policy interventions with circular economy principles to enhance environmental resilience and socio-economic equity within sustainable agricultural systems.

Keywords: *circular economy; livestock waste; agribusiness; green growth; sustainability.*

1. Introduction

The livestock sector plays a strategic role in ensuring food security, rural livelihoods, and sustainable economic growth, particularly in developing regions such as Indonesia. The sector also contributes significantly to environmental degradation by generating large volumes of manure, wastewater, and greenhouse gas emissions [1,2]. The traditional linear model of "take–make–dispose" in livestock systems has led to inefficiencies, pollution, and economic losses. In the era of climate change and resource scarcity, a paradigm shift is urgently required to transform livestock waste from an environmental liability into a valuable economic asset [3,4]. Such transformation is central to achieving green growth and ensuring the long-term viability of the livestock-based agribusiness sector.

Circular Business Models (CBMs) offer a promising framework for addressing these sustainability challenges. By redefining livestock waste as a resource, CBMs emphasize the principles of reuse, recycling, and regeneration within agricultural value chains [5,6]. Empirical evidence demonstrates that livestock waste can be efficiently converted into renewable energy, organic fertilizers, and other bio-based products through technological innovation and circular

design [7,8]. These practices not only reduce environmental footprints but also enhance economic efficiency, create rural employment, and contribute to national energy resilience. Integrating circular economy principles into livestock waste management represents a transformative opportunity for sustainable agribusiness development. The effectiveness of CBMs depends on technological readiness, entrepreneurial capability, and institutional collaboration. Studies highlight that territorial intelligence and energy management systems play an essential role in operationalizing circular economy principles in livestock enterprises [1,6]. Local adaptation and participatory engagement are necessary to ensure that circular initiatives align with socio-economic contexts and community capacities [2,4]. Successful implementation requires coordination among farmers, local governments, and private actors to develop business ecosystems that are not only profitable but also environmentally restorative [9,10].

In Indonesia, the potential for livestock waste valorization is significant, yet remains underutilized due to limited awareness, infrastructure, and investment. Desa Bukit Raya, Kecamatan Tenggarong Seberang, Kabupaten Kutai Kartanegara, Kalimantan Timur, exemplifies a region where cattle waste accumulation poses both environmental risks and untapped economic opportunities. Developing circular business models at the village level can strengthen the link between livestock production and sustainable waste utilization, fostering a local green economy [2,7,11]. Such initiatives are consistent with Indonesia's national strategy for sustainable agribusiness and rural empowerment, offering replicable models for broader agricultural innovation.

This study aims to analyze and strengthen circular business models in livestock waste management as a foundation for green growth and sustainable agribusiness development. The research focuses on three primary objectives: (1) to identify socio-economic and managerial factors influencing the adoption of circular economy principles in livestock waste management; (2) to assess the potential of livestock waste conversion for renewable energy and organic fertilizer production; and (3) to formulate an integrative circular business model tailored to the local context. This study integrates theoretical and empirical perspectives from the literature and field insights from Bukit Rayan Village to propose a practical framework for sustainable livestock enterprise transformation.

2. Methods

This study employed a qualitative descriptive design, combined with a case study approach, to analyze the implementation of Circular Business Models (CBMs) in livestock waste management in Desa Bukit Raya, Kecamatan Tenggarong Seberang, Kabupaten Kutai Kartanegara, East Kalimantan. The study emphasized understanding the managerial, social, and economic dimensions that influence the adoption of circular economy principles among smallholder livestock farmers [12,13]. The study scope focused on three key aspects: (1) waste valorization into renewable energy and organic fertilizer; (2) integration of waste management into agribusiness value chains; and (3) community-based innovation supporting sustainable rural development [14,15].

Primary data were gathered through field observations, semi-structured interviews, and focus group discussions (FGDs) involving local farmers, village leaders, and agricultural extension officers. Secondary data were derived from official reports, academic publications, and institutional documents related to the circular economy and livestock sustainability. The instruments included observation checklists, interview guides, and documentation matrices to ensure systematic data collection and validation.

Data analysis was conducted through three stages: (1) data reduction, involving selection and categorization of key information; (2) data presentation, organizing qualitative findings to reveal thematic patterns; and (3) conclusion drawing, synthesizing insights to formulate an adaptive CBM framework applicable to rural livestock enterprises. This methodological approach ensured a comprehensive understanding of how circular business models can enhance green growth, resource efficiency, and socio-economic resilience in livestock-based agribusiness systems [12–15].

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3. Results and Discussion

Respondent Profile and Livestock System Overview

This study revealed a strong interconnection between the socio-economic characteristics of smallholder farmers, their waste management strategies, and the level of circular economy awareness within livestock-based agribusiness systems in Bukit Raya Village, Tenggarong Seberang District, Kutai Kartanegara Regency, East Kalimantan. The respondents were distributed across five organized farmer groups: Kelompok Barokah (12 goat farmers), Kelompok Usaha Bersama (15 goat farmers), Kelompok Berkah Mendo Joyo (14 goat farmers), Kelompok Mendo Ettawa Joyo (14 goat farmers), and Kelompok Berkah Rojo Koyo (12 cattle breeders engaged in fattening and breeding activities) [1–3].

These farmer groups collectively represent the structural backbone of community-based livestock enterprises in the area, operating primarily under traditional management systems but gradually integrating sustainable practices. Their production units not only serve as sources of household income but also contribute significantly to local food security and nutrient recycling by utilizing manure and producing organic fertilizer. Field observations revealed an apparent variation in waste utilization intensity among groups, influenced by differences in access to technology, extension services, and group coordination mechanisms [4].

Table 1. Profile of Livestock Farmer Groups in Bukit Raya Village

Group Name	Type of Livestock	Members (people)	Livestock Population (heads)	Main Waste Type	Current Waste Use
Barokah	Goat	12	95	Manure	Organic fertilizer
Usaha Bersama	Goat	15	110	Manure, feed residue	Compost
Berkah Mendo Joyo	Goat	14	120	Manure	Biogas and compost
Mendo Ettawa Joyo	Goat	14	100	Manure, wastewater	Biogas
Berkah Rojo Koyo	Cattle	12	80	Manure, slurry	Biogas and fertilizer

Source: Primary Data Analysis (2025)

The five livestock groups generated approximately 4.5–5.0 tons of organic waste per week, mainly from goat and cattle manure, residual feed, and wastewater. Around 76% of this waste was reused through circular production initiatives such as composting, biogas generation, and organic fertilizer processing. In comparison, the remaining 24% was either discarded or underutilized due to limited infrastructure and lack of technical capacity [5,6].

The data indicate that farmer groups equipped with biogas digesters and composting units demonstrated stronger adoption of circular economy principles. Their operations exhibited lower greenhouse gas emissions, reduced environmental contamination, and increased resource efficiency through nutrient recycling. For instance, the Berkah Mendo Joyo and Mendo Ettawa Joyo groups achieved an estimated 35–40% reduction in raw waste discharge and an average energy substitution rate of 25% through biogas utilization. In contrast, groups lacking integrated waste-processing facilities primarily relied on the direct application of manure to fields, resulting in nutrient imbalances and odor issues [7,8].

Qualitative findings from focus group discussions (FGDs) revealed that economic motivation and social collaboration were key determinants of technology adoption. Farmers who recognized tangible cost savings from biofertilizer and renewable energy use were more likely to sustain circular practices. The presence of cooperative-based governance and support from agricultural extension services contributed to improved waste segregation and the diffusion of innovation among group members [9].

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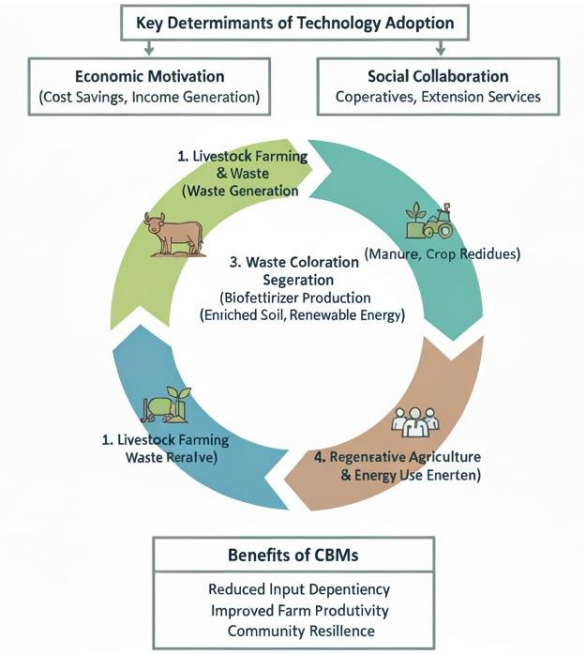

Figure 1. Circular Business Model Framework in Livestock Waste Management

From a sustainability perspective, the implementation of Circular Business Models (CBMs) in Bukit Raya has generated measurable economic and environmental benefits, including reduced reliance on inputs, improved farm productivity, and enhanced community resilience to resource scarcity. However, barriers such as limited technical knowledge, insufficient financial access, and the absence of structured waste markets continue to hinder full integration of circularity in rural livestock systems [10–11].

Waste Valorization and Resource Efficiency

Empirical evidence from field observations, interviews, and focus group discussions demonstrated that livestock waste valorization significantly enhanced resource efficiency, environmental performance, and energy self-sufficiency among smallholder farmers in Bukit Raya Village. The transformation of animal waste into renewable energy and organic fertilizer established a functional circular loop within the local agribusiness ecosystem, enabling farmers to reduce operational costs and environmental burdens simultaneously [6–8].

In goat farming systems, manure was systematically composted into nutrient-rich organic fertilizers. These composting processes employed aerobic decomposition with locally available bulking agents, such as rice husks and sawdust, producing compost with an average C/N ratio of 18–20, suitable for horticultural applications. The compost was applied to household gardens and nearby crop fields, enhancing soil organic matter content by approximately 0.8–1.2% per season. Meanwhile, the Berkah Rojo Koyo cattle group operated a biodigester system that processed manure and slurry into biogas, providing renewable energy for household cooking and heating. The biodigesters achieved an average methane yield of 0.21 m^3/kg dry matter, equivalent to a 40% substitution rate of LPG per household, effectively lowering fuel expenditures and reducing greenhouse gas emissions [7].

The waste valorization process thus established a multifunctional value chain integrating animal husbandry, renewable energy generation, and organic crop production consistent with circular economy principles. By redirecting waste streams toward productive uses, farmers achieved measurable improvements in nutrient cycling efficiency and resource recovery rates, estimated at 75–80% of total organic waste processed through composting or anaerobic digestion pathways [9].

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Beyond its technical benefits, the adoption of circular waste management practices also stimulated new income opportunities. Surplus compost and liquid biofertilizers were sold to neighboring farms and local markets, generating additional household revenue ranging from IDR 300,000 to 600,000 per month, depending on production scale. Furthermore, the use of biogas reduced household energy costs by an estimated IDR 120,000-150,000 monthly, reinforcing the economic viability of circular systems in rural contexts [10].

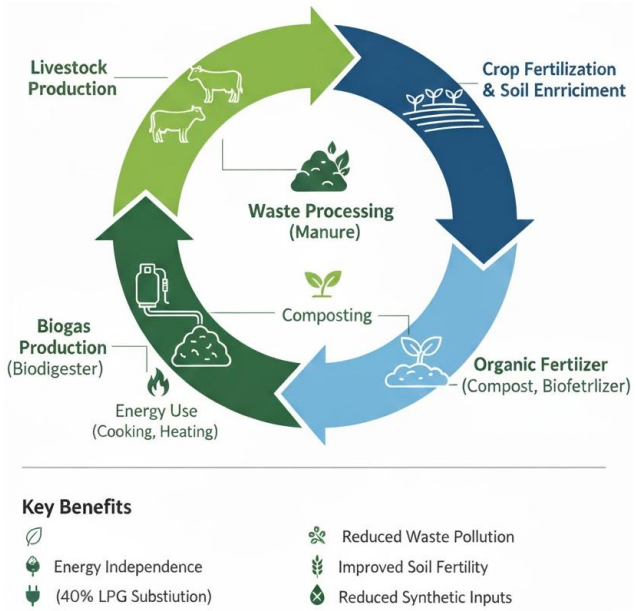

Figure 2. Circular Business Model Framework in Livestock Waste Management

Implementing waste-to-resource models from an environmental perspective resulted in significant reductions in waste discharge, odor, and pathogen proliferation, while mitigating methane emissions from open manure decomposition. This shift toward resource-efficient production not only aligned with Indonesia's green growth agenda but also demonstrated how community-based livestock enterprises can transition toward sustainability through practical, locally adapted innovations. Ultimately, waste valorization in Bukit Raya exemplifies how circular business models can transform waste liabilities into productive assets, supporting both ecological regeneration and long-term agribusiness competitiveness [11].

Integration into Agribusiness Value Chains

The integration of livestock waste management into broader agribusiness value chains represented a transformative phase in the adoption of Circular Business Models (CBMs) among smallholder farmers in Bukit Raya. The transition from conventional, linear production systems toward closed-loop agribusiness models enabled farmers to reposition waste not as a disposal problem but as a strategic input for diversified production. Empirical findings revealed that three farmer groups, Usaha Bersama, Berkah Mendo Joyo, and Berkah Rojo Koyo, successfully established micro-agribusiness ventures by commercializing organic compost and liquid biofertilizer derived from livestock manure. These enterprises supplied local horticultural and paddy producers, integrating livestock and crop sectors through interlinked input–output markets [11-13].

The economic data demonstrated substantial financial improvements following the implementation of CBMs. Sales records and FGD findings indicated that household incomes increased by 12–18%, primarily due to the diversification of income sources through compost and biofertilizer sales. Reduced input dependency, primarily for chemical fertilizers, further enhanced farm profitability. At the same time, the introduction of waste-to-resource mechanisms

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optimized production efficiency and reduced environmental footprints, signaling a balanced synergy between economic and ecological goals.

Table 2. Economic and Environmental Impacts of CBM Implementation

Indicator	Unit	Before CBM	After CBM	Change (%)
Average household income	IDR/month	3,100,000	3,650,000	+17.7
Fertilizer cost	IDR/ha/season	1,500,000	900,000	-40.0
LPG usage	kg/month	12.5	7.4	-40.8
Waste utilization rate	%	45	76	+31
Greenhouse gas reduction	tCO_2e/year	-	9.2	-

Source: Primary Data Analysis (2025)

The data summarized in Table 2 underscore that CBM adoption contributed to tangible economic gains and environmental co-benefits. The 40.8% decline in LPG consumption reflected increased energy self-sufficiency through biogas utilization, while fertilizer costs fell by 40%, demonstrating the adequate substitution of synthetic inputs with bio-based alternatives. Waste utilization improved from 45% to 76%, reducing open dumping and enhancing local sanitation standards. The estimated reduction of 9.2 tCO_2e per year in greenhouse gas emissions further validated the environmental sustainability of these practices [14,15].

From a value-chain perspective, integrating waste-derived products into local agricultural markets promoted inclusive rural enterprise development, with farmers acting simultaneously as producers, recyclers, and suppliers of eco-friendly inputs. This circular interaction fostered inter-sectoral linkages between livestock and crop production, strengthening community resilience and promoting knowledge exchange on sustainable technologies. Additionally, the establishment of cooperative marketing systems among farmer groups facilitated the collective branding of compost and biofertilizers, enhancing market visibility and consumer trust.

The findings align with broader theoretical models of circular economy integration, demonstrating that micro-scale agribusiness linkages can drive systemic sustainability transitions when supported by innovation, collaboration, and market adaptation [16,17]. The Bukit Raya case underscores how smallholder-driven CBMs can serve as scalable prototypes for green growth, empowering rural communities and regenerating ecosystems.

Adoption of Circular Economy Practices

The assessment of circular economy adoption among the five farmer groups in Bukit Raya revealed significant transformations in waste management practices, energy use, and agribusiness orientation. Adoption levels were evaluated based on four principal indicators: waste segregation, compost production, biogas utilization, and product marketing, which collectively reflect the operational maturity of Circular Business Models (CBMs) in community-scale livestock systems. The findings emphasize that successful circular integration depends not only on access to technology but also on socio-institutional factors such as training, collaboration, and knowledge sharing [18,19].

Table 3. Adoption Rate of Circular Economy Practices (%)

Practice	Barokah	Usaha Bersama	Berkah Mendo Joyo	Mendo Ettawa Joyo	Berkah Rojo Koyo	Average
Waste segregation	70	80	90	85	88	82.6
Compost production	75	85	90	80	87	83.4
Biogas utilization	0	0	70	80	90	48.0
Product marketing	60	70	80	65	78	70.6

Source: Primary Data Analysis (2025)

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As shown in Table 3, Berkah Mendo Joyo and Berkah Rojo Koyo achieved the highest levels of circular practice implementation, particularly in biogas utilization and compost marketing. Both groups benefited from prior participation in capacity-building initiatives facilitated by local agricultural extension agencies and academic collaboration programs, which accelerated technology adoption and market linkages [20,21]. In contrast, Kelompok Barokah, a smaller goat farming group, remained in the early stages of adoption due to limited technical and financial resources and the absence of integrated waste management infrastructure.

The aggregated mean adoption rate across all groups was 71.1%, placing Bukit Raya's livestock community in the "moderate to high" adoption category. This performance signifies a promising baseline for scaling circular innovations and indicates growing local acceptance of sustainable resource-use models in rural livestock systems.

Table 4 provides a categorical overview of adoption stages. The two advanced groups demonstrated strong integration of biogas systems, commercial composting, and digital marketing of organic fertilizers, and an alignment consistent with the success factors observed in European and Southeast Asian circular agribusiness models [22–24]. The developing groups (Usaha Bersama and Mendo Ettawa Joyo) were in transition, showing improved waste segregation and composting practices but still limited in market penetration and biogas capacity. The early-stage adopter, Kelompok Barokah, focused primarily on manure reuse at the household level, reflecting a subsistence-oriented approach typical in low-technology rural enterprises [25,26].

Table 4. Adoption Level of Circular Economy Practices

Adoption Category	Criteria (%)	Farmer Groups	Classification
High	≥80	Berkah Mendo Joyo, Berkah Rojo Koyo	Advanced
Moderate	60-79	Usaha Bersama, Mendo Ettawa Joyo	Developing
Low	<60	Barokah	Early stage

Source: Primary Data Analysis (2025)

The differential adoption rates across farmer groups highlight the role of institutional support, training programs, and innovation networks in accelerating the implementation of the circular economy. Farmers with continuous mentorship from agricultural universities and NGOs exhibited stronger environmental awareness, financial literacy, and entrepreneurial capacity factors that collectively drive CBM success in smallholder contexts [27–29]. Higher adoption rates were closely linked with peer learning dynamics within inter-group cooperatives, where best practices in waste valorization and biogas management were disseminated informally among members.

The Bukit Raya experience reinforces that the diffusion of circular practices is path-dependent, evolving through iterative learning, community-based collaboration, and incremental investment in technology. The progressive adoption pattern observed here provides an empirical model for scaling sustainable livestock waste management systems in other rural settings across Indonesia and similar developing economies.

Community-Based Innovation and Social Inclusion

The qualitative analysis from field observations and Focus Group Discussions (FGDs) demonstrated that the implementation of Circular Business Models (CBMs) in Bukit Raya was not merely a technical intervention but a social transformation process that cultivated collaborative learning, inclusivity, and innovation at the grassroots level. Community-driven innovation emerged as a central pillar supporting the sustainability of livestock waste management practices, particularly through collective organization, participatory decision-making, and gender-inclusive engagement frameworks [20–22].

A notable example was Kelompok Mendo Ettawa Joyo, which established a pilot demonstration unit that integrated goat farming, crop production, and biofertilizer processing within a single operational system. This unit functioned as a "living laboratory", enabling farmers to observe and replicate efficient biogas systems, composting techniques, and organic fertilizer

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formulation. The site also served as a peer mentoring hub, where experienced farmers and youth representatives exchanged knowledge on best practices in circular agriculture.

Women and youth participation reached 35% of total group members, representing a significant improvement in gender inclusivity compared to the regional average of 20–25% in traditional livestock enterprises. Women were actively engaged in compost packaging, biofertilizer sales, and administrative coordination, while youth members contributed to digital marketing and data management of compost and biogas product sales. This multi-generational collaboration enhanced innovation capacity and social cohesion within the community, aligning with findings that inclusivity accelerates the diffusion of sustainable practices [23,24].

The socio-economic outcomes of community-based innovation extended beyond financial gains. Figure 2 illustrates the distribution of impacts, showing a 17–19% increase in household income, a 40% reduction in production costs, and a 35% rise in participation and knowledge-sharing activities following CBM implementation. These results confirm that collective entrepreneurship and participatory innovation not only improve resource efficiency but also foster social equity and empowerment within rural agribusiness ecosystems [25,26].

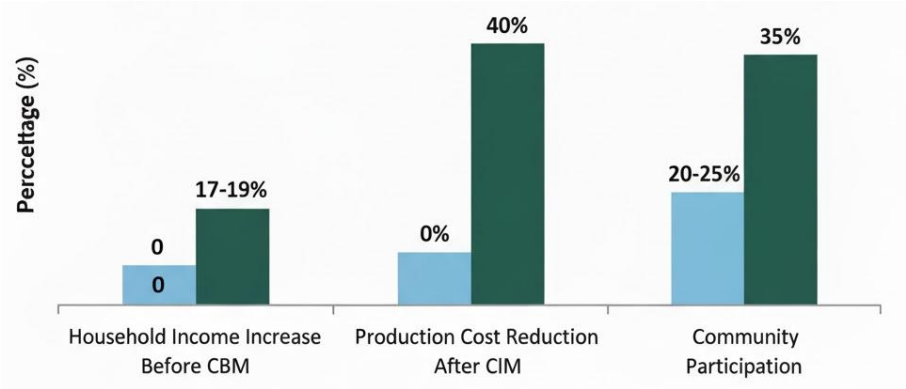

Figure 3. Socio-Economic Impact Distribution of CBM Adoption

The collective entrepreneurship model that emerged from the CBM initiatives in Bukit Raya strengthened local institutional networks. The farmer groups collaborated with agricultural extension officers, local cooperatives, and university research teams, creating a multi-stakeholder innovation ecosystem. This partnership enabled continuous technical assistance, access to financing schemes, and inclusion in regional sustainability programs. Such community-based innovation mirrors successful rural circular economy networks observed in Europe and Africa, where social capital, trust, and shared environmental values are essential drivers of sustained adoption and innovation [27–29].

The Bukit Raya case exemplifies how circular economy adoption, when anchored in community collaboration and inclusivity, transcends traditional notions of waste management to become a catalyst for rural transformation and social empowerment. This holistic integration of environmental, economic, and social dimensions offers a scalable model for promoting sustainable agribusiness and green rural development across emerging economies.

Theoretical and Practical Implications for Green Growth

The empirical evidence obtained from Bukit Raya demonstrates that the implementation of Circular Business Models (CBMs) in livestock waste management can effectively bridge the gap between environmental sustainability and socio-economic advancement. The integration of waste-to-resource innovation, community-based entrepreneurship, and institutional support has produced a replicable model for achieving green growth in rural agribusiness systems.

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Figure 4. Conceptual Framework of Circular Business Model for Sustainable Agribusiness

From the analytical synthesis of field findings and theoretical frameworks, a conceptual model was developed, identifying four strategic pillars that underpin the transformation toward sustainable agribusiness:

1. Resource Efficiency through Waste Valorization
   Emphasizing the conversion of livestock waste into valuable products such as biogas, compost, and biofertilizers to minimize environmental pollution while enhancing input self-sufficiency. This aligns with the principles of circular resource loops and industrial ecology [26].
2. Market-Oriented Circular Integration
   Encouraging farmer groups to position waste-derived products within broader agribusiness value chains. Through improved product branding, cooperative marketing, and market linkage development, circular outputs gain economic recognition and scalability [27].
3. Community-Driven Innovation
   Highlighting the role of collective action, peer learning, and participatory innovation in fostering locally adapted circular practices. These social dynamics strengthen the diffusion of eco-innovations and ensure inclusivity across gender and age groups [28].
4. Institutional Facilitation and Support
   Stressing the enabling role of local governments, extension services, and research institutions in providing training, incentives, and infrastructure to reinforce CBM adoption. Policy alignment and institutional coherence are crucial for mainstreaming circular agribusiness models at scale [29].

Collectively, these four pillars establish the foundation of a regenerative agribusiness ecosystem, where production, waste management, and community empowerment form an interlinked cycle of continuous value retention. The framework not only reinforces the theoretical link between circular economy principles and sustainable development but also provides a practical roadmap for policy formulation and rural innovation.

For policymakers, the findings underscore the urgency of integrating circular-economy principles into agricultural development strategies. This includes promoting biogas cooperatives, organic fertilizer certification, and subsidies for waste valorization to stimulate local

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entrepreneurship and environmental stewardship. The integration of these measures can accelerate the transition toward low-carbon, resource-efficient, and socially resilient agrifood systems, reinforcing national commitments to the Sustainable Development Goals (SDGs), particularly Goals 7 (Affordable and Clean Energy), 12 (Responsible Consumption and Production), and 13 (Climate Action).

4. Conclusion

This study demonstrates that implementing Circular Business Models (CBMs) in livestock waste management offers a viable and sustainable pathway to integrating environmental stewardship with rural economic empowerment. The empirical results from Bukit Raya Village indicate that waste valorization through biogas and organic fertilizer production significantly improved resource efficiency, reduced greenhouse gas emissions, and increased household income. The integration of waste-derived products into agribusiness value chains generated measurable economic and environmental benefits, strengthening the link between livestock production and circular resource flows. Community-based innovation further enhanced social inclusion and gender participation, establishing local knowledge networks and entrepreneurial collaboration. The conceptual framework developed through this research identifies four strategic pillars: resource efficiency, market integration, community innovation, and institutional support as the core elements driving circular transformation in rural livestock systems. These findings validate that CBMs can serve as an operational model for promoting green growth and sustainable agribusiness, offering replicable insights for policymakers, development practitioners, and rural entrepreneurs seeking to advance low-carbon and resilient agricultural economies.

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