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Development of Circular Economy in Waste Logistics Management in Lembang District, West Bandung Regency

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Abstract. *This study aims to develop the concept of circular economy as a solution for waste management in West Bandung Regency, especially in Lembang District. Data from the National Waste Management Information System shows that in 2022, Indonesia will produce 67.8 million tons of waste, with 185,753 tons of waste produced daily by 270 million residents. Lembang District has a population of 202,603 people in 2022, waste management is a significant problem because the burning method often used by rural communities, resulting in air pollution and health risks. Agriculture is the dominant sector with 32% of the population working as farmers and 36.6% involved in this sector. Organic agricultural waste is projected to reach 140,767 tons/day in 2026, requiring an effective management strategy. Circular Economy offers a solution through an approach that maximizes the use and added value of raw materials, reduces waste, and supports green economic growth. Key stakeholders include the village government, BUMDes, farmers, MSMEs, and health clinics, collaborating to implement composting, biogas, and waste reduction initiatives. This model not only improves soil quality but also enhances the economic and environmental sustainability of Lembang through waste management and value-added local products.*

Keywords: *sustainability, waste, agriculture, logistics, Indonesia.*

I. INTRODUCTION

Indonesia faces a mounting waste management crisis. In 2023, 202 regencies and cities reported that national waste generation reached 21.1 million tons (Kementerian Koordinator Bidang Pembangunan Manusia dan Kebudayaan, 2023). On average, approximately 0.68 kilograms of waste is generated per person each day, amounting to around 185,753 tons daily by the 270 million population (Setiawan, 2021). As urbanization and population growth continue, the volume of waste increases, posing severe challenges for local governments.

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One such area experiencing these challenges is West Bandung Regency (KBB), particularly Lembang District, which had a population of 202,603 in 2022 spread across 16 villages (Kusuma & Senja, 2023; BPS Kabupaten Bandung Barat, 2023). Many parts of Lembang, especially rural villages, lack formal waste collection systems. In response, open waste burning remains a prevalent practice. Unfortunately, this method contributes to air pollution and public health risks, releasing harmful substances such as nitrogen oxides, carbon monoxide, and particulate matter (Ferronato & Torretta, 2019). Prolonged exposure can lead to respiratory illnesses, reproductive disorders, and chronic diseases, including cancer (Rendi et al., 2021).

As population growth increases, so does the volume of daily waste. Educating the public on proper waste management methods that avoid burning is essential. Community awareness of the environmental impacts of waste burning is crucial, as continuing to burn waste as the primary disposal method could exacerbate global warming, lead to fires, and cause water and air pollution.

In 2022, Indonesia generated a total of 81.87 million tons of hazardous waste and 60.58 million tons of non-hazardous waste. This waste originated from mining, energy, oil and gas,

manufacturing, food industries, agro-industries, and medical waste (Liyantono et al., 2022). Around 53% of industrial waste is managed by the producers themselves, with the remainder handled by third parties.

The urgency of this issue is compounded by limited local infrastructure and weak waste management services. Improper waste disposal not only threatens environmental quality but also undermines social well-being, increases health expenditures, and may exacerbate disaster risks (Zhang et al., 2022; Nguyen & Khominich, 2023; Purnamadewi et al., 2019). In 2022, Indonesia also generated over 142 million tons of industrial waste, more than 47% of which was managed by third parties, further emphasizing the nation's systemic waste management challenges (Liyantono et al., 2022).

Table 1. Environmental Quality Index Value in West Java

Percentage (%)	Goal	Achieved
Water Quality Index	34.7578	32.6578
Air Quality Index	33.1703	33.3578
Land Quality Index	34.9766	33.2734

Table 1 shows the West Java region has different quality index levels across three categories depending on the degree of environmental pollution. The water quality index had a target of 42.87% and an achievement of 43.09%, indicating that the government has successfully encouraged the public to comply with water quality policies for waste management. The land quality index had a target of 38.8% and an achievement of 40.78%, which suggests that waste management in the land category is considered good. However, this is not the case for the air quality index, which had a target of 79.71% but only achieved 79.34%. This shows that waste management related to air pollution has not been maximized.

The circular economy is a holistic economic approach designed to maximize the utility and added value of raw materials, components, and products (Gandolfo & Lupi, 2021). This model reduces the amount of unused material disposed of in landfills, contributing to a higher green economic growth compared to traditional practices (Badan Standarisasi Nasional, 2022). The circular economy is a system where materials never become waste, and natural ecosystems are regenerated (Voulgaridis et al., 2022).

The circular economy is built on three design-driven principles: eliminating waste and pollution, circulating products and materials at their highest value, and regenerating natural systems (Oliveira & Oliveira, 2022). This approach benefits businesses, communities, and the environment by facilitating the transition to renewable energy and materials. Waste management is a significant issue faced globally, with poorly managed waste leading to environmental, health, and natural resource challenges (Desiyanti, 2023). The circular economy presents an innovative and sustainable approach to waste management, transforming waste from a disposal problem into a valuable resource (Sutomo et al., 2022).

In the circular economy, the primary goal is to minimize waste and reduce environmental impacts through maximizing reuse (Papamichael et al., 2023), recycling (Papamichael et al., 2023), and material recovery Komkova & Habert, 2023). This model relies on product and system innovations to ensure the longevity and optimal use of materials. The circular economy both contributes to environmental preservation (Cheng et al., 2023) and creates new economic (Isoaho et al., 2024) and social value, such as community empowerment (Selvan et al., 2023). When implemented, it provides a sustainable solution that requires collaboration among all stakeholders which are governments, private sectors, and communities (Marjamaa et al., 2021) across all waste management cycles. These cycles include waste minimization, recycling, reuse, and final treatment, which involve sorting, collecting, transporting, processing, and final disposal.

The circular economy model is one of the approaches that can support the sustainable development goals (SDGs) in striving for zero waste by 2030 (Karamustafa et al., 2022). Countries like the Netherlands, Finland, China, and Japan have incorporated the circular

economy into their national agendas. Factors motivating these nations to adopt circular economy practices include the scarcity of natural resources, resource price volatility, and the depletion of resources due to continuous extraction to meet human needs (Fadhillah & Fahreza, 2023).

The formulas for projection methods in three forms (Astiti, 2023; Harsiti et al., 2022; Rusdiansyah et al., 2020) are presented as follows: the arithmetic method formula, the geometric method formula, and the least squares method formula, which will be displayed as Eq. (1), Eq. (3), and Eq. (4).

$$Pn = P0 + Ka\ (Tn - T0) \quad \ldots (1)$$

$$Ka = \frac{P1 - P2}{T1 - T2} \quad \ldots (2)$$

With:

- Pn: population in year n (people)
- Po: population in the initial year (people)
- Tn: year (n)
- To: base year
- Ka: arithmetic constant
- P1: known population in the first year
- P2: known population in the last year
- T1: known first year
- T2: known final year

$$Pn : Po\ (1 + r)\ n \quad \ldots (3)$$

With:

- Pn: population in year n (people)
- Po: population in the initial year (people)
- r: annual population growth rate
- n: number of year intervals

$$Y = a + bx \quad \ldots (4)$$

$$a = \frac{(\sum Y)(\sum X\ 2) - (\sum X)(\sum XY)}{(\sum X2) - (\sum X)\ 2} \quad \ldots (5)$$

$$b = \frac{n\ (\sum X.Y) - (\sum X)(\sum Y)}{n\ (\sum X2) - (\sum X)\ 2} \quad \ldots (6)$$

With:

- Y: value of the variable based on the regression line
- X: independent variable
- a: constant
- b: coefficient of the linear regression slope
- n: number of data points

This research introduces a localized circular economy model tailored specifically for rural waste management in Lembang District. Unlike conventional urban-focused strategies, this model is designed to reflect Lembang's agrarian character and decentralized settlements. It emphasizes stakeholder collaboration, promotes the processing of agricultural and household waste into compost and biogas, and offers economic incentives through the production of value-added goods such as organic fertilizer and renewable energy. The model not only seeks to reduce environmental pollution and health risks associated with burning but also strengthens community livelihoods and aligns with Sustainable Development Goals (SDGs), particularly the goal of zero waste by 2030.

The circular economy has emerged as a transformative framework for sustainable waste management, aiming to decouple economic growth from resource consumption by promoting reuse, recycling, and material recovery (Ghisellini et al., 2022). In rural contexts, however, its application remains limited, particularly in low- and middle-income countries where centralized infrastructure is scarce. Recent studies have highlighted the importance of tailoring circular economy models to local socio-economic and environmental conditions (Chakraborty & Mishra, 2021; Papamichael et al., 2023).

In Indonesia, efforts to integrate circular principles into waste management systems have largely focused on urban or industrial sectors (Desiyanti, 2023; Fadhillah & Fahreza, 2023), with minimal emphasis on community-based agricultural waste solutions in peri-urban or rural areas. Biogas and composting technologies have shown promise in agricultural settings (Selvan et al., 2023; Komkova & Habert, 2023), but empirical research on the integration of these technologies within decentralized, stakeholder-driven models remains sparse. This paper addresses that gap by proposing a localized circular economy model specifically designed for Lembang District which is a rural region with a dominant agricultural livelihood.

This research aims to develop the concept of a circular economy as a solution for waste management in the area. The implementation of this method is expected to reduce waste volume, minimize the negative environmental impact of waste, and provide benefits to the local community.

The originality of this study lies in its integration of demographic mapping, waste quantification, and community-based strategies into a scalable and replicable model tailored to the needs of agrarian communities in Indonesia. Unlike existing frameworks, which often adopt top-down or sectoral approaches, this model emphasizes stakeholder collaboration, resource recovery, and decentralized systems suited for rural governance and infrastructure limitations.

II. RESEARCH METHOD

This research adopts a mixed-methods approach to understand the dominant livelihood patterns in Lembang District and assess the environmental impact of agricultural waste, as part of designing a localized circular economy model.

The study begins with a demographic and occupational mapping of Lembang District. This phase uses structured questionnaires and Geographic Information System (GIS) tools to identify the primary livelihoods of residents across the district's 16 villages. Spatial data collected will be visualized to understand settlement patterns and the distribution of agricultural activities.

A desk study will be conducted to review existing literature on agricultural waste management and rural circular economy practices. Secondary data on waste generation which categorized by waste type and volume (tons/day) will be sourced from the Portal Satu Data Kabupaten Bandung (2024) and other credible government publications. This review provides the baseline for identifying key waste streams and management gaps in the region. To validate secondary data and gather contextual insights, field visits will be conducted in selected villages. Observations will assess current waste handling practices, particularly related to agricultural by-products. A structured survey will also be distributed to key stakeholders, including local farmers, waste handlers, and government officials. The survey aims to capture knowledge, attitudes, and practices (KAP) related to waste disposal, composting, and potential biogas use.

Collected data will be cleaned and processed to identify patterns in agricultural waste generation. Using statistical projection techniques, including arithmetic and geometric methods, the study will forecast daily agricultural waste volumes for the years 2024 to 2026, based on observed trends from 2021 to 2023. Waste types such as crop residues, livestock waste, and organic household waste will be analyzed separately.

Findings from the data analysis will be synthesized into a localized circular economy model tailored to Lembang's agricultural profile. The model will incorporate strategies such as decentralized composting, biogas production, and waste segregation systems. Effectiveness will be evaluated against sustainability criteria, including environmental impact reduction, community engagement potential, and economic feasibility.

The study will conclude by identifying key challenges and opportunities in agricultural waste management in rural contexts. Recommendations will emphasize actionable interventions that promote waste valorization and stakeholder collaboration. Local government bodies, farmers, and community groups will be targeted for engagement to ensure sustainable implementation of the proposed circular economy model.

III. RESULT AND DISCUSSION

The primary occupation of the residents in Lembang District is agriculture, with 32% of the population engaged as farmers. This significant portion highlights the crucial role that agriculture plays in the local economy and community livelihood.

Agricultural activities in Lembang District generate various types of waste. The waste is

categorized into three main types: organic, non-organic, and hazardous waste (B3). The average proportion of organic waste is 80%, making composting a viable alternative for handling this waste (Ketut, 2015). Non-organic waste, such as plastic and used pesticide containers, constitutes 15%, while hazardous waste, which includes pesticide residue, makes up 5%.

Table 2 presents the agricultural waste output in Kabupaten Bandung Barat, segmented by type from 2021 to 2023. Organic waste increased from 132,178 tons per day in 2021 to 135,638 tons in 2023. Non-organic waste showed a smaller increase, from 16,522 tons in 2021 to 16,955 tons in 2023. Hazardous waste (B3) also saw a slight rise from 8,261 tons in 2021 to 8,477 tons in 2023.

Table 2. Agricultural Waste Based on Type (ton/day)

Waste Type	2021	2022	2023
Organic	132.178	133.723	135.638
Non-organic	16.522	16.715	16.955
B3	8.261	8.358	8.477

Table 3. Production Quantity of Vegetable, Fruit, and Biopharmaceutical Plants

	2020	2021	2022
Tomato (vegetable)	24.370	26.145	16.350
Banana (fruit)	200	41.418	23.428
Ginger (Biopharmaceutical)	8.500	6.950	15.850

Table 4. Livestock Population by District and Type of Livestock, 2021-2022 (heads)

	2021	2022
Cow	22.863	22.748
Sheep	15.240	15.683
Goat	1.659	1.595

Table 5. Amount of Agricultural Waste by Type, 2021-2026 (tons/day)

Year	Waste Type		
	Organic	Non Organic	B3
2021	132.178	16.522	8.261
2022	133.723	16.715	8.358
2023	135.638	16.955	8.477
2024	137.307	17.163	8.582
2025	139.037	17.380	8.690
2026	140.767	17.596	8.798

Agricultural output in Lembang District includes vegetables, fruits, and biopharmaceutical (medicinal plants). Table 3 shows the production quantities for key crops between 2020 and 2022. Tomato production peaked at 26,145 tons in 2021 but then declined to 16,350 tons in 2022. Banana production experienced significant variation, with a peak of 41,418 tons in 2021, dropping to 23,428 tons in 2022. Meanwhile, ginger production fluctuated, declining from 8,500 tons in 2020 to 6,950 tons in 2021 before rising to 15,850 tons in 2022.

The livestock population in Lembang District, as recorded between 2021 and 2022, indicates a relatively stable population of dairy cows, sheep, and goats. Table 4 details these figures. Dairy cow numbers slightly decreased from 22,863 in 2021 to 22,748 in 2022. The sheep population increased from 15,240 in 2021 to 15,683 in 2022, while the goat population experienced a minor decline from 1,659 in 2021 to 1,595 in 2022.

Based on the data collected on the livelihoods of residents in Lembang District, 32% chose to work as farmers. Agricultural activities in Lembang District generate various types of waste, including organic waste, non-organic waste, and hazardous waste (B3). The historical data available can be used as a projection to illustrate the waste output for the next three years as follows.

The projected results for agricultural waste over the next three years indicate a significant increase. In 2024, organic waste is expected to reach 137,307 tons per day, reflecting an increase of 1,669 tons per day from 2023. Non-organic waste in 2024 is projected to reach 17,163 tons per day, an increase of 208 tons per day from 2023. Hazardous waste (B3) is anticipated to rise to 8,582 tons per day in 2024, marking an increase of 105 tons per day from 2023.

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With a focus on proper management and enhancing the added value of agricultural and livestock products, Lembang District can continue to develop and improve the well-being of its residents. The concept of a circular economy can be applied to promote the welfare of living beings in harmony with the environment.

Based on the issues outlined, a circular economy model can be implemented to optimize resource use, reduce waste, and improve both economic and environmental welfare. The circular economy model in Lembang District is driven by seven main pillars aimed at promoting sustainability. It begins with the BUMDes, which play a crucial role in initiating and regulating policies that support circular economy practices. The agricultural sector produces organic waste, which can then be used as feed for livestock. This leads to the second pillar: agricultural waste. Farmers manage this organic waste to provide nutrient-rich feed for livestock, such as cows, sheep, and chickens, ensuring the cycle continues efficiently.

The third pillar focuses on livestock farming, where animals consume the organic waste. Healthy livestock, in turn, become the source of manure, which is then processed into high-quality fertilizer. To ensure the well-being of both livestock and the environment, clinic services come into play, offering medical care and educational resources related to animal health and proper feeding practices.

The next pillar involves converting livestock manure into compost, a crucial step in creating nutrient-rich fertilizer. This fertilizer, as outlined in the sixth pillar, is applied to the soil to improve fertility and support sustainable agriculture. MSMEs (Micro, Small, and Medium Enterprises) play a vital role by adding value to agricultural and livestock products, such as turning raw crops into processed goods for distribution and sale. This cycle leads to enriched soil, supporting continuous agricultural productivity and contributing to a self-sustaining and economically prosperous community in Lembang.

This integrated approach not only promotes a circular economy that enhances resource efficiency, supports economic development, and protects the environment but also represents an advancement over traditional circular economy models. Unlike urban-focused frameworks, this model prioritizes cross-sectoral loops in rural settings, addressing unique challenges such as organic waste integration and stakeholder collaboration.

Implementing a circular economy model in Lembang District comes with several potential challenges. Effective coordination and collaboration among various stakeholders, such as local governments, BUMDes, farmers, livestock farmers, MSMEs, and the community, are crucial. Adequate funding and investment will be necessary to build the required infrastructure and support sustainable initiatives. Raising public awareness and providing education on circular economy practices are also essential to encourage active participation (Voitko et al, 2022). Moreover, advanced technology and infrastructure, while potentially costly and complex, are necessary for efficient waste processing and resource management (Naiho et al., 2024).

While earlier circular economy studies have emphasized resource loops in urban and industrial contexts, this research contributes significantly by integrating agricultural waste and livestock cycles, fostering local economic development. For example, the inclusion of clinic services for livestock and the value-added activities of MSMEs are novel additions that ensure both environmental and economic benefits.

In addition to the circular economy, integrating concepts like Lean and Green productivity can offer valuable insights into improving waste management practices. These concepts, already successfully implemented in industries such as food production and construction, focus on reducing inefficiencies while promoting environmental sustainability. Tools like Value Stream Mapping (VSM) and Material Balance Diagrams (MBD) are particularly relevant, as they can be adapted to monitor waste

flows, identify inefficiencies, and support better decision-making in agricultural waste management (Purnomo & Lukman, 2020).

Furthermore, unlike existing studies that focus solely on minimizing waste, this research explores the availability and optimization of markets and distribution channels to ensure the economic viability of circular products. Regulatory frameworks and supportive policies must also be established to facilitate smooth implementation. Effective waste management, requiring innovative solutions to handle different types of waste sustainably, remains a key challenge.

Lastly, ensuring the long-term sustainability of this model will require continuous monitoring, adaptation, and the commitment of all involved parties.

By addressing gaps in previous circular economy research and introducing a comprehensive, community-based approach, this study provides a scalable and replicable framework for rural regions aiming to enhance both environmental and economic impacts.

IV. CONCLUSION

This research proposes a localized circular economy model tailored to the waste management challenges of Lembang District, where 32% of residents are engaged in agriculture. The model leverages the district's waste composition which comprising 80% organic, 15% non-organic, and 5% hazardous materials by integrating key stakeholders into a closed-loop, value-generating system. Village governments and BUMDes play a strategic role in establishing enabling policies, building waste processing infrastructure, and facilitating community training. Farmers and livestock producers contribute organic residues and manure for composting and biogas production, while MSMEs enhance value through the transformation of by-products into marketable goods. With 22,748 dairy cows recorded in 2022, livestock manure emerges as a significant resource within this model. Meanwhile, clinics ensure livestock health and quality outputs, and fertilizer producers convert organic waste into high-quality compost, improving soil fertility and reducing environmental pollution.

Projected waste generation in West Bandung Regency by 2026 which 140,767 tons/day of organic waste, 17,596 tons/day of non-organic waste, and 8,798 tons/day of hazardous waste underscores the urgency of adopting sustainable, community-driven solutions. The proposed circular economy model presents a practical and inclusive pathway to reduce waste volumes, strengthen rural economies, and mitigate environmental degradation.

This study offers a novel contribution by demonstrating how circular economy principles can be effectively adapted for rural settings through decentralized, stakeholder-led collaboration. Future research should focus on enhancing community awareness, scaling infrastructure investments (e.g., composting units, biogas digesters), and developing policy incentives such as subsidies or green financing for MSMEs. Long-term evaluation of the model's economic and environmental impacts is also recommended to assess its scalability and replicability in other agrarian communities. By addressing these factors, Lembang District can serve as a replicable model for rural regions pursuing sustainable and inclusive development.

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