

Potential, Economic-Environmental Feasibility, and Biomass Waste Management Strategy for People's Oil Palm Replanting in East Tanjung Jabung Regency, Jambi Province

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Abstract

Introduction: Oil palm replanting in smallholder plantations generates substantial biomass waste, including trunks, fronds, and roots. In Tanjung Jabung Timur Regency, Jambi Province, which has the largest 2026 replanting target in the province, the potential and management strategies for this waste remain unexplored.

Objective: This study aimed to estimate biomass waste potential, evaluate economic and environmental feasibility, and formulate management strategies. **Method:** A descriptive quantitative approach was applied using Plantation Office data, supported by interviews and an FGD involving ten key informants from five stakeholder groups. **Result and Discussion:** Waste potential was estimated at 88.4 tonnes per hectare, consisting of trunks (61.2 tonnes), fronds (13.6 tonnes), and roots (13.6 tonnes). The organic fertilizer processing scheme (48,000 tonnes/year) showed feasibility with an NPV of IDR 77.08 billion and BCR of 1.58. WCAS identified a Quadrant I strategy emphasizing circular economy-based biomass utilization. **Conclusion:** Oil palm replanting waste represents a valuable resource for sustainable rural development.

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Introduction

Indonesia is the leading global producer of palm oil, contributing more than half of the world's total output. In 2021, the country produced 46.88 million tons of palm oil, establishing itself as the primary exporter of crude palm oil (CPO). Major palm oil plantations are located in regions such as Sumatra and Kalimantan, with Jambi Province serving as a key production center. In 2023, Jambi Province covered 1,006,000 hectares of plantation area and produced 7.25 million tons of Fresh Fruit Bunches (FFB) annually (BPS Provinsi Jambi, 2023). To sustain the productivity of aging smallholder plantations, the government, through the Palm Oil Plantation Fund Management Agency (BPDPKS), has implemented the Smallholder Palm Oil Replanting Program (PSR). This initiative seeks to improve smallholder productivity by replacing old plants with certified superior seedlings. (Harahap et al. 2025) It also advances farmer welfare and plantation sustainability. (Maulana et al. 2025). By 2023, BPDPKS reported that the program had encompassed over 300,000 hectares of smallholder land, providing financial assistance of Rp.30 million per hectare, with the amount scheduled to increase to Rp.60 million per hectare in August 2025. This planned increase underscores the government's commitment to enhancing smallholder palm oil productivity (Deli et al. 2024)

Within this policy context, East Tanjung Jabung Regency emerges as a critical case due to its low productivity and substantial areas of Unproductive/Damaged Plants (TTM/TR) and Immature Plants (TBM), highlighting an urgent need for replanting. Data from Jambi Province indicate that this regency has the lowest productivity in the province, at only 2,073 kg/ha. The presence of 8,898 hectares of TTM/TR and 13,782 hectares of TBM further substantiates this assessment (Dinas Perkebunan Provinsi Jambi, 2024). Despite these challenges, PSR realization data from 2016 to 2024 reveal that East Tanjung Jabung Regency has not recorded any replanting under the PSR scheme, whereas seven other regencies have collectively replanted 24,693.4 hectares (Dinas Perkebunan Provinsi Jambi, 2024). This lag is consistent with studies indicating that independent smallholder participation in the PSR is hindered by administrative barriers, limited initial financing, and insufficient technical assistance in several areas of Jambi (Hasbullah et al. 2025).

In this context, the 2026 target allocation shifts substantially. Tanjung Jabung Timur Regency is set to receive the largest PSR allocation in Jambi Province, with 1,500 hectares, representing approximately 19.23 percent of the province's total target of 7,800 hectares. This allocation significantly exceeds those of other regencies, which range from 300 to 750 hectares. (Sihombing et al., 2025). As a result, the increased replanting targets are expected to generate substantial volumes of biomass waste, particularly oil palm trunks and fronds. Each hectare of replanted oil palm plantation is estimated to produce 60–80 metric tons of wet oil palm trunks, with a moisture content of 60-70 percent. (Deli et al., 2024). Open burning of replanting biomass can generate substantial particulate pollution, particularly fine particulate matter (PM_{2.5} and PM₁₀), in addition to greenhouse gases such as CO₂ and CH₄. Inhalation of these pollutants may irritate the respiratory tract, reduce air quality, and increase respiratory health risks, particularly among farmers and communities living near plantation areas. Meanwhile, unmanaged biomass accumulation may contribute to soil and water contamination through decomposition and create favorable conditions for disease vectors and pests. Thus, inappropriate biomass management can create both environmental degradation and direct public health risks (Anisah et al. 2025).

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Various studies indicate that oil palm replanting waste has economic value that remains underexplored. In line with circular economy principles, this biomass waste can be converted into value-added products. These include biomass pellets, biogas through anaerobic digestion, or bioethanol through fermentation; sustainable agricultural inputs such as compost, liquid organic fertilizer, or biochar (Ika et al. 2024); green industrial raw materials such as particleboard, nanocellulose, or technical lignin; and micro-business ecosystems for farmer groups, cooperatives, or MSMEs engaged in local-scale waste processing. Yet realizing this potential is hampered by structural factors: limited waste treatment infrastructure and collection logistics; low technical capacity and limited access to appropriate technology; lack of economic incentives and specific policy support; and poor coordination among stakeholders, from farmers and plantation companies to local governments and research institutions (Stefani et al. 2025). From an environmental health perspective, the relationship between oil palm replanting waste and community health can be conceptualized through the following pathway: increased replanting activities → increased biomass waste generation → inappropriate disposal or open burning → increased particulate and gaseous emissions → deterioration of ambient air quality → human exposure through inhalation → respiratory health effects. An alternative sustainable pathway involves biomass collection and utilization → reduced open burning and waste accumulation → lower environmental pollutant exposure → improved environmental quality and reduced health risks. This framework positions biomass management not only as an economic and environmental issue, but also as an environmental health intervention

Most previous research on regional strategies for utilizing palm oil waste has relied on conventional descriptive SWOT analysis without incorporating stakeholder salience weighting. As a result, identifying strategic factors often depends on researchers' subjective assessments and lacks clear traceability to field data. For example, a study on palm oil wastewater management in Riau and West Sulawesi used observations and descriptive interviews without stratifying the influence of different actors. (Karno et al. 2024). Moreover, East Tanjung Jabung Regency is unique because its waste primarily originates from community-led reforestation efforts rather than processing plants. This results in an exceptionally large projected waste volume due to the 2025–2026 PSR targets. Even so, this context has not been specifically examined in terms of potential estimates, economic and environmental feasibility, or utilization strategies. To address this research gap, the present study aims to: (1) identify the potential of oil palm replanting biomass waste in East Tanjung Jabung Regency; (2) analyze the economic and environmental potential of managing this waste using a Cost-Benefit Analysis (CBA) approach; and (3) formulate management strategies through a Weighted Content Analysis SWOT (WCAS) approach involving ten key informants representing various stakeholder groups. The study is expected to contribute theoretically by providing an analytical framework that integrates estimates of resource potential, economic and environmental feasibility, and strategies grounded in auditable field evidence. Practically, it aims to deliver a database and policy recommendations for local governments, BPDPKS, and other stakeholders to support the sustainable management of oil palm replanting waste.

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Method

This study was conducted in East Tanjung Jabung Regency, Jambi Province, selected purposively because it received the largest PSR allocation in 2026 (1,500 hectares) and had not been specifically studied regarding replanting waste potential and utilization strategies. Secondary data collection began in April 2026, and the FGD was conducted on June 6, 2026. Data collection used triangulation through: (1) literature review of official documents and technical references to estimate biomass waste potential; (2) semi-structured interviews with stakeholders and waste managers to obtain economic data; and (3) FGDs with key stakeholders to formulate management strategies. This study applied a qualitative approach with non-probability purposive sampling (Wibowo et al., 2021). Interview participants included stakeholders and farmers experienced in biomass waste management, while the FGD involved ten key informants representing government agencies, academics, farmer groups, environmental advocates, and PSR contractors based on the Stakeholder Salience Model (Pramono et al. 2025). Biomass waste potential was calculated using $N = A \times P$ and $L = N \times B$, where A represents replanting area, P represents planting density (136 trees/ha) based on Indonesian oil palm standards (Sastrosayono, 2003), and B represents biomass weight per tree obtained from the Directorate General of Plantations (2022) and farmer validation. Economic and environmental feasibility was analyzed using Cost-Benefit Analysis (CBA) with a five-year projection and 10 percent discount rate. The analysis included costs (Sulistiani, 2016), benefits, NPV, and BCR, incorporating both financial value and environmental value through shadow pricing. (Maulana et al., 2025).

Management strategies were developed using Weighted Content Analysis SWOT (WCAS), integrating content analysis with stakeholder weighting based on the Stakeholder Salience Model (Alpandari et al., 2021). This model evaluates stakeholders based on three attributes: power (ability to influence decisions), legitimacy (formal and scientific), and urgency (issue urgency and degree of direct impact) (Maulana et al., 2025). Stakeholders with all three attributes (definitive stakeholders) receive the highest weight (3), while those with more limited salience but still relevant (expectant stakeholders) receive a moderate weight (2). The WCAS analysis process follows the logical flow of qualitative content analysis open coding of FGD transcripts line by line; axial coding into strategic themes; categorization of themes into internal factors (IFAS: Strengths and Weaknesses) and external factors (EFAS: Opportunities and Threats); calculation of theme frequencies by stakeholder and weighting based on the Stakeholder Salience Model; conversion of Weighted Frequency into IFAS/EFAS weights and ratings; development of an IFAS-EFAS matrix and (Septiawan & Thohari, 2014) determination of SWOT quadrant positions following (Alpandari et al., 2021), framework; and formulation of the SO-WO-ST-WT strategy matrix, grounded entirely in textual evidence from the FGDs rather than generic formulations.

Result and Discussion

1. Result

Overview of the Study Area

East Tanjung Jabung Regency, located in the easternmost part of Jambi Province, encompasses a land area of 5,445 km² and a coastline measuring approximately 191 km, which constitutes about 90.5 percent of the province's total coastline (Dinas Perkebunan

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Provinsi Jambi, 2024). The region experiences a wet tropical climate, with an average temperature of 27.0°C and an average annual rainfall of 2,875 mm. Organic and peat soils dominate the area, accounting for 60 percent of the total soil composition. In 2025, oil palm plantations in the regency covered 41,432 hectares and produced 76,399 metric tons. Mendahara Ulu Subdistrict contained the largest plantation area, totaling 18,062 hectares. The majority of these plantations were established during the smallholder oil palm expansion between the 1990s and early 2000s. Consequently, many oil palm trees are now over 25 years old, resulting in a significant decline in productivity and necessitating replanting through the PSR program facilitated by BDPKPS.

Table 1

Data on the 2025 PSR Actual Results and the 2026 PSR Targets for East Tanjung Jabung Regency in the Context of Jambi Province

Region	PSR 2025 Implementation (ha)	Target PSR 2026 (Ha)	Contribution to the Provincial Total (%)
Kab. Tanjung Jabung Timur	330.83	1.500,00	5,08 (real.) / 19,23 (target)
Total for Jambi Province	6.512.38	7.800,00	100,00

Source: Jambi Provincial Plantation Office (2026).



Figure 1. Comparison of the 2025 PSR Actual Results and the 2026 PSR Targets for East Tanjung Jabung Regency Compared to Jambi Province

The figure above shows a sharp increase in the target allocation for East Tanjung Jabung Regency from the 2025 actual figure to the 2026 target, while the growth in the total target for Jambi Province is relatively more moderate. The growth rate of this regency's target (4.5 times the 2025 actual figure) far exceeds the growth rate of the provincial target (1.2 times), confirming that East Tanjung Jabung Regency will be the region with the most significant acceleration in replanting in Jambi Province in 2026, meaning that the estimated biomass waste generation in this region will also surge proportionally (Dinas Perkebunan Provinsi Jambi, 2024).

The Potential of Oil Palm Replanting Waste

Table 2 indicates that East Tanjung Jabung Regency has a target area of 1,500 hectares for the 2026 PSR Program, which is equivalent to the targets set for Batang Hari and Merangin Regencies. In 2025, only 330.83 hectares were rejuvenated in East Tanjung Jabung Regency, representing approximately 22.05 percent of the target. This achievement constitutes about 5.08 percent of the total PSR implementation in Jambi Province, while the 2026 target for the regency accounts for approximately 19.23 percent of the province’s overall PSR target.

The estimation of potential oil palm replanting waste in this study is based on the average biomass weight per oil palm tree at the replanting stage, which includes three primary components: roots, fronds, and trunks. (Sihombing et al., 2025). The biomass weight per tree was determined using technical data from the Directorate General of Plantations (2022) and validated through interviews with farmers who had conducted replanting. According to these interviews, roots and fronds each weighed approximately 1 pikul (100 kg), while the trunk weighed about 4.5 pikul (450 kg). Consequently, each hectare of rejuvenated oil palm plantation in East Tanjung Jabung Regency is estimated to generate 88.4 metric tons of biomass waste. Trunks constitute the largest portion (61.2 metric tons per hectare or 69.23 percent), followed by fronds and roots in equal amounts (13.6 metric tons per hectare or 15.38 percent each), as detailed in Table 2.

Table 2
Potential Oil Palm Replanting Waste per Hectare (Density: 136 trees/ha)

Components	Biomass/Trees (kg)	Waste Potential (ton/ha)	Contribution (%)
Root	100	13.60	15.38
Palm frond	100	13.60	15.38
Stem	450	61.20	69.23
Total	650	88.40	100.00

Source: Data processed by the researcher (2026), based on the Directorate General of Plantations (2022) and confirmation from field interviews.

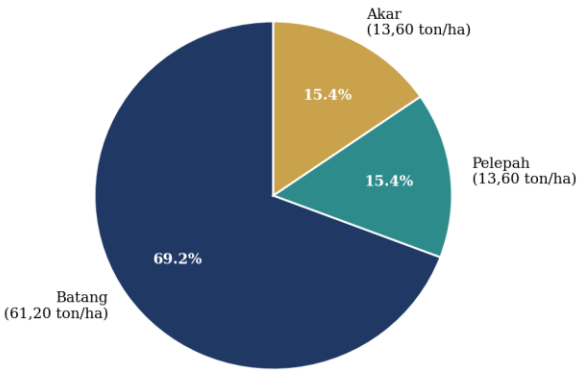


Figure 2. Composition of Potential Biomass Waste from Oil Palm Replanting per Hectare

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The pie chart confirms that oil palm trunks are the dominant component of waste, accounting for nearly 70 percent of the total biomass produced per hectare of replanted land. Accordingly, priorities for the development of processing infrastructure should first focus on handling stem waste for both biomass energy and industrial raw materials before expanding to process fronds and roots, which, while much smaller in volume, remain relevant as raw materials for compost.

Based on the 2025 PSR implementation covering 330.83 hectares, the potential biomass waste generated in East Tanjung Jabung Regency is estimated at 29,245.37 metric tons. By contrast, based on the 2026 PSR target allocation covering 1,500 hectares, the potential waste volume could increase to 132,600 metric tons. This estimated stem yield of 61.2 metric tons per hectare is consistent with field data reporting a range of 60–80 metric tons of wet oil palm stems per hectare during replanting activities and, in terms of order of magnitude, is consistent with the estimate of national oil palm biomass production, which reaches 261.7 million metric tons of dry matter per year from a total area of 16.8 million hectares. (Hasbullah et al., 2025; Harahap et al., 2025).

Based on the characteristics of each biomass component, potential uses can be categorized as follows: stem waste (starch-sugar content of 14–48 percent) can be processed into high-calorie biomass flour (4,300–4,500 kcal/kg), used as a raw material for particleboard, converted to second-generation bioethanol, or used as a solid fuel for biomass boilers or coal-fired power plant co-firing; palm frond waste is generally used as livestock feed (silage), raw material for organic fertilizer or compost, or raw material for pulp; meanwhile, root waste is relatively more difficult to collect because it is buried in the ground, so it can be left to decompose naturally to improve soil fertility or partially collected as compost material. Based on the results of the FGD, organic fertilizer was identified as the most promising utilization pathway for development, with oil palm fronds accounting for 20 percent of the total raw materials, in line with current practices in one of the farmer groups.

The Economic and Environmental Potential of Waste Management

The feasibility of a scheme to process organic waste (rice husks, cow manure, fiber, and oil palm fronds) into organic fertilizer with a capacity of 48,000 metric tons per year was analyzed using a cost-benefit analysis (CBA). The total initial investment (CAPEX) is Rp.1,149,999,990, covering land lease, construction of a fermentation warehouse, a shredder, transport vehicles, scales, occupational safety and health (K3) equipment, permits, and contingency costs. Annual operating costs total Rp34,116,000,000, including variable costs of Rp.31,536,000,000 for raw materials, decomposers, and packaging, and fixed costs of Rp.2,580,000,000 for salaries, electricity, fuel, and maintenance.

For environmental benefits, three components of the shadow price were considered: savings on solid waste management costs (48,000 metric tons $\times$ Rp.50,000 = Rp.2,400,000,000), reductions in methane emissions converted into carbon offset values (28,800 metric tons of CO₂e $\times$ Rp.30,000 = Rp.864,000,000), and ecological restoration and soil fertility (48,000 metric tons $\times$ Rp.100,000 = Rp.4,800,000,000). Total environmental benefits amount to Rp.8,064,000,000 per year. On the environmental cost side, odor mitigation via biofilters and wastewater treatment plants (Rp.150,000,000 per year) and compensation for logistics-related dust emissions (Rp.200,000,000 per year) total Rp.350,000,000 per year. The environmental benefit-cost ratio is approximately 23

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to 1, indicating that every rupiah spent on environmental mitigation generates ecological benefits worth about 23 rupiah, as summarized in Table 3.

Table 3
 Cost Structure and Economic-Environmental Valuation of an Organic Fertilizer Business (48,000 metric tons/year)

Components	Value (IDR/year, unless otherwise stated)
Initial investment (CAPEX, Year 0)	1.149.999.990
Variable cost (raw materials, decomposer, packaging)	31.536.000.000
Fixed costs (salary, electricity, fuel, maintenance)	2.580.000.000
Total Financial Operating Costs	34.116.000.000
Environmental benefits — waste handling savings	2.400.000.000
Manfaat lingkungan — reduksi emisi metana (carbon offset)	864.000.000
Environmental benefits — ecological restoration & soil nutrients	4.800.000.000
Total environmental benefits (shadow price)	8.064.000.000
Environmental mitigation costs (bio-filters, WWTP, logistics dust)	350.000.000

Source: Data processed by the researcher (2026).

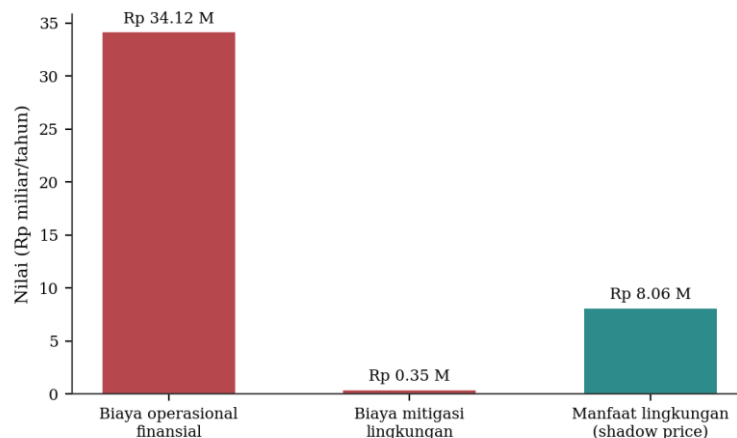


Figure 3. Comparison of Operating Cost Structures and Environmental Benefits of Organic Fertilizer Businesses

The graph visually illustrates that financial operating costs (Rp.34.12 billion/year) far outweigh environmental mitigation costs (Rp.0.35 billion/year) in the cost structure, while the resulting environmental benefits (Rp.8.06 billion/year) amount to nearly one-fifth of the financial operating costs a significant contribution given their nature as non-market benefits, which have rarely been factored into the feasibility assessments of conventional waste management operations. The CBA analysis was conducted on projected cash flows over five years of operation, using a 10 percent annual discount rate. The benefit components include financial revenue from product sales (48,000 metric tons

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× Rp.980,000 = Rp.47,040,000,000 per year) and environmental benefits (Rp.8,064,000,000 per year), bringing total annual benefits for Years 1–5 to Rp.55,104,000,000. On the cost side, the components include initial investment, operating costs, and environmental mitigation costs, with total annual costs for Years 1 – 5 amounting to Rp.34,466,000,000.

The cash flow projection results show a Net Present Value (NPV) of Rp.77,084,257,357 and a Benefit-Cost Ratio (BCR) of 1.58, indicating that this business plan is feasible both financially and from an economic and environmental perspective. By comparison, if environmental valuation is not included in the calculation (a purely financial analysis), the present value (PV) of financial benefits is only Rp.178,318,609,633, with the PV of financial costs at Rp.130,476,481,415, resulting in a financial BCR of 1.37. In other words, internalizing environmental value into the CBA increases the BCR from 1.37 to 1.58 over the five-year horizon, confirming that environmental benefits are not merely a supplementary component but a significant contributor (approximately 14.6 percent of total annual benefits) to the feasibility of this organic waste treatment project, as summarized in Table 5.

Table 4
Summary of Economic Feasibility (Discount Rate 10%, 5-Year Horizon)

Indicators	Purely Financial Scenario	Scenarios with Environmental Valuation
PV Benefits (kumulatif)	Rp 178.318.609.633	Rp 208.887.514.141
PV Cost (kumulatif)	Rp 130.476.481.415	Rp 131.803.256.784
Net Present Value (NPV)	–	Rp 77.084.257.357
Benefit-Cost Ratio (BCR)	1,37	1,58
Eligibility Status	Appropriate	Appropriate

Source: Data processed by the researcher (2026).

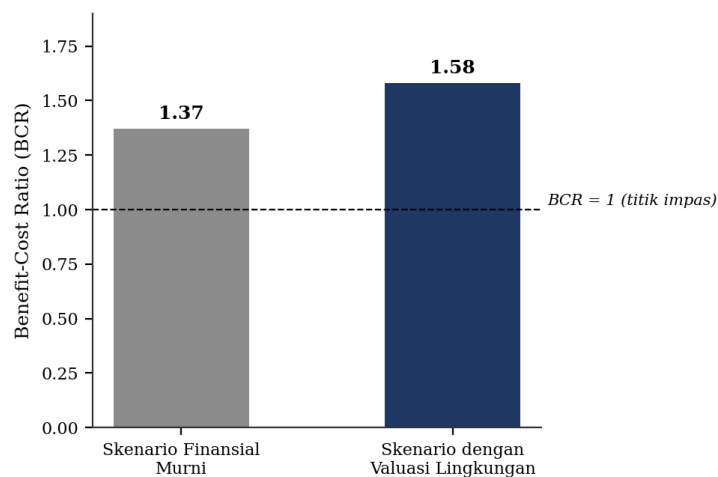


Figure 4. Comparison of the Benefit-Cost Ratio (BCR) Between the Purely Financial Scenario and the Scenario Incorporating Environmental Valuation

Both scenarios in the graph lie above the break-even line ($BCR = 1$), showing the waste treatment project remains viable without accounting for environmental benefits. Internalizing environmental values increases the BCR by about 15.3 percent (from 1.37 to 1.58), clarifying that the project's viability strengthens when policymakers and investors include carbon-based incentive schemes (carbon credits) or payments for environmental services. The BCR value of 1.58 in this study falls within the upper range compared to feasibility studies on the management of similar organic waste in Indonesia. For example, the valuation of the Batu Layang Landfill in Pontianak reported a BCR of 1.25 based on the Contingent Valuation Method, while a farmer-group-scale organic cow manure fertilizer initiative reported a benefit-cost (B/C) ratio of 7.13 (Maulana et al., 2025). The high BCR in this study is likely due to three main factors: first, the presence of direct financial revenue from the sale of compost products at a relatively high selling price (Rp.980,000/ton); second, the inclusion of three complementary environmental benefit components (waste reduction, emission reduction, and ecological restoration); and third, the relatively low environmental mitigation costs compared to the scale of the benefits generated.

Waste Management Strategies for Oil Palm Replanting

The WCAS analysis of FGD transcripts from ten key informants yielded 195 open codes, which were grouped through axial coding into 34 internal factor themes (IFAS) and 37 external factor themes (EFAS). In the “Strengths” factor, “Readiness of Technology and Processing Infrastructure” was the most dominant theme with the highest weighted frequency, followed by “Academic Research Support and Policy Advocacy” and “Abundant Availability of Raw Materials.” In the “Weaknesses” factor, “Limitations in the Technical Quality of Processed Products” was the most significant barrier, followed by “Limited Economic Viability and Economies of Scale” and “Limitations in Human Resources and Farmer Succession.” On the opportunities side, “Advocacy for Mandatory Waste Management Regulations” and “Export Market Demand for Biomass Products” were the most dominant themes, reflecting the convergence of policy drivers and market demand. On the threats side, farmers’ limited access to initial financing and price fluctuations of derivative products were major concerns for some informants. (Pramono et al., 2025).

Based on the weighted IFAS-EFAS matrix, the internal factor with the highest score is “Technology and Processing Infrastructure Readiness” (weighted score 0.3177). The external factors with high scores are “Advocacy for Mandatory Waste Management Regulations” and “Biomass-Based Energy Self-Sufficiency.” The difference between the total scores for strengths and weaknesses (X-axis) and for opportunities and threats (Y-axis) places the strategic position of oil palm replanting waste management in East Tanjung Jabung Regency in Quadrant I (Aggressive). This indicates dominant strengths and opportunities. Accordingly, the Strengths-Opportunities (SO) strategy is the top priority, as summarized in Table 5.

Table 5
Summary of the SWOT (SO) Strategy Matrix for Oil Palm Replanting Waste Management

Prioritas	Strategi SO	Faktor Pendukung Utama (IFAS/EFAS)
1	Pilot project for integrated composting using renewable energy, led by a farmers' group	Technology Readiness (S) + Biomass Energy Self-Sufficiency (O)
2	Advocacy for mandatory regulations on the use of locally sourced compost	Academic Research Support (S) + Advocacy for Mandatory Regulations (O)
3	Downstream processing of waste-based export products (pellets, briquettes, fiber pellets, veneer)	Abundant Availability of Raw Materials (S) + Export Market Demand (O)
4	Expanding the integrated cattle-palm oil-compost circular economy model to all farmer groups	Circular Economy Model (S) + Job Creation (O)

Source: Results of the Weighted Content Analysis SWOT (WCAS), FGD on June 6, 2026.

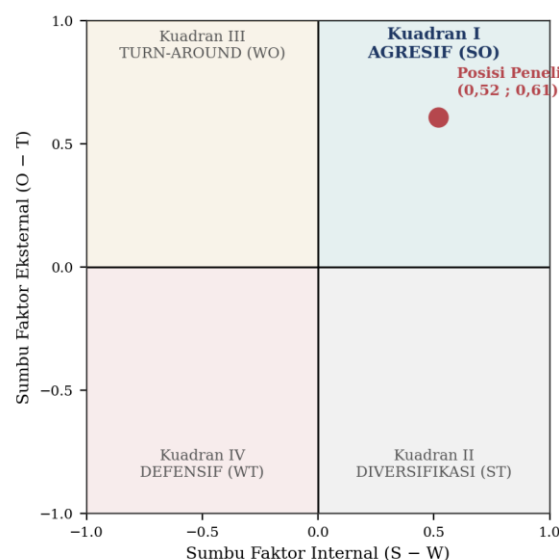


Figure 5. Strategic Quadrant Positions for Oil Palm Replanting Waste Management Based on WCAS

The point (0.52; 0.61) on the SWOT diagram lies well within Quadrant I, indicating that internal strengths and external opportunities are both strong and balanced. This gives stakeholders plenty of room to take bold actions without needing to fix big internal weaknesses or deal with major external threats first, as would be necessary in the other quadrants. The top strategy was chosen because it combines the highest IFAS and EFAS scores and can be initiated by farmer groups with the skills to serve as pilot examples for other PSR villages. The second strategy builds on legal precedent in the palm oil sector, thanks to the Indonesian Sustainable Palm Oil (ISPO) certification, which supports the use of similar policies to require the use of local compost. The third strategy is supported by strong market demand: Indonesia can produce 11 million metric tons of palm kernel shells each year, but only about 3.5 million metric tons are exported, mainly to Japan,

leaving significant potential for more processing. The fourth strategy aims to expand these efforts to more farmer groups across the regency, moving toward a circular-economy zone model rather than the micro-enterprise approach used previously.

2. Discussion

This study shows that waste from smallholder oil palm replanting, which is less studied than waste from processing plants such as POME, shells, and empty fruit bunches, has significant potential in both volume and economic value. The estimated 88.4 metric tons per hectare of total waste matches figures from national technical data (BPDP, 2026) and large-scale national oil palm biomass production estimates. (Deli et al., 2024). When looking at these numbers, it is important to consider differences in measurement methods, geographic coverage, and data collection periods. While that study used community willingness to pay, this study uses shadow prices for ecological benefits. Both approaches show that including environmental values in feasibility analysis gives a more complete view of economic feasibility than financial analysis alone. (Maulana et al., 2025).

Research in Indonesia has shown that compost made from palm oil waste, such as empty fruit bunches and fronds, is effective for agriculture (Hasbullah et al., 2025). The main challenge now is not technical, but about putting the scheme into practice through policies and regulations that create market certainty. Existing rules in the palm oil sector, such as the Indonesian Sustainable Palm Oil (ISPO) certification, suggest that similar regulations could require large plantation companies to use compost made from local waste. This matches the second strategic priority of this WCAS study. These findings also support the technical and economic feasibility of using palm oil biomass for renewable energy, as evidenced by the Palm Oil Biomass Power Plant (PLTBS) study, which reported financial viability with a positive NPV (Mohammad et al. 2021). This supports the idea that combining a pilot composting project with renewable energy, as suggested in this study, is practical within the wider context of palm oil biomass in Indonesia.

The WCAS in this study produced a Quadrant I (Aggressive) position, which aligns with results from other SWOT-based studies on palm oil waste use in Indonesia that also identify strong development opportunities. The WCAS method stands out because its strategies can be clearly traced back to specific stakeholder themes and weights, making them easier to audit and repeat. This is different from most studies, which use descriptive SWOT analysis without considering the influence of different actors. (Dahniar, 2017). By combining estimates of waste potential, economic and environmental feasibility assessments through CBA, and strategies informed by field evidence, the WCAS framework can be applied to other smallholder oil palm replanting areas in Indonesia facing similar issues. However, this study is limited because the interviews and focus group discussions covered only one district, and the processing scheme has not yet been tested in the field. Future research, including pilot projects and post-implementation monitoring, will help confirm these findings.

The findings of this study have conceptual implications for environmental health, particularly in relation to sustainable biomass waste management in oil palm replanting areas. Although this study did not directly measure air quality parameters, pollutant exposure, or health outcomes, inappropriate biomass disposal practices such as uncontrolled burning may potentially influence environmental conditions through increased emissions and particulate pollution. Therefore, implementing sustainable waste

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utilization strategies may contribute to reducing potential environmental risks by minimizing unmanaged biomass accumulation and avoiding open burning practices.

From an environmental health perspective, the proposed waste management pathway can be conceptualized as: increased oil palm replanting activities → increased biomass waste generation → selection of waste management practices → changes in environmental quality. This pathway highlights that effective biomass utilization strategies may provide environmental co-benefits by reducing waste-related environmental pressures. However, further studies involving direct measurements of particulate matter, emission levels, exposure assessment, and health indicators are required to evaluate actual environmental health outcomes

Conclusion

This study highlights three main findings. First, oil palm replanting biomass waste in East Tanjung Jabung Regency reaches 88.4 metric tons per hectare, with potential generation of 29,245.37 metric tons in 2025 and 132,600 metric tons based on the 2026 target. Second, the evaluated organic fertilizer processing scheme (48,000 metric tons/year) shows economic and environmental feasibility, with an NPV of Rp77,084,257,357 and BCR increasing from 1.37 to 1.58 when environmental benefits are included. Third, the SWOT analysis identifies an 'Aggressive' position with strategies focusing on biomass utilization infrastructure, supportive regulations, downstream processing, and circular economy development.

These results indicate that replanting biomass can be developed as a valuable resource through circular economy approaches. Stakeholders should focus on strengthening biomass utilization policies, improving processing infrastructure, and expanding pilot waste management models. The potential contribution of biomass management to land-fire risk reduction is an environmental implication requiring further study, as it was not directly assessed in this research

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