

Baseline assessment of household waste generation in a remote tropical region: Jayapura, Indonesia

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Abstract: Reliable information on household waste generation and composition is essential for developing effective waste management strategies, particularly in geographically remote regions with limited infrastructure. This study aimed to assess household waste generation rates, waste composition, and associated socioeconomic and spatial characteristics in Jayapura Regency, Papua, Indonesia. We conducted a cross-sectional quantitative study involving 400 households across five districts representing urban, semi-urban, and rural areas. Researchers measured household waste over eight consecutive days following SNI 19-3964-1995 and analyzed the data using descriptive statistics, inferential statistics, and spatial analysis. The study reported an average household waste generation rate of 0.48 kg/person/day, with higher rates in urban areas (0.56 kg/person/day) than in rural areas (0.35–0.42 kg/person/day). Organic waste made up the largest share of household waste (62.5%), followed by plastic waste (18.3%). These findings indicate substantial differences in waste generation patterns across the study areas and highlight the importance of considering local waste characteristics in infrastructure planning. The results provide preliminary baseline information to support the development of geographically differentiated household waste management strategies in Jayapura Regency

Keywords: *household waste generation; waste composition; urban-rural differences; solid waste management*

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INTRODUCTION

Municipal solid waste management has emerged as a critical challenge in rapidly developing regions (Kaza et al., 2018). Indonesia generates 67.8 million tonnes annually, with only 67.1% adequately managed (Ministry of Environment and Forestry, 2020). The challenge is particularly acute in remote regions where research remains limited.

Papua Province exhibits unique characteristics: rapid economic growth (6.8%/year), geographical isolation, and limited infrastructure. Despite representing 22% of Indonesia's land area, Papua accounts for only 2.4% of waste management research (Damanhuri et al., 2014). This geographical bias creates critical knowledge gaps with serious policy implications.

Jayapura Regency (17,516 km²; population 178,043) demonstrates remarkable economic dynamism (7.2% annual growth) and population increase (2.8%/year), substantially exceeding national averages. However, only 31.6% of districts have formal waste collection access, serving just 35% of the population. Current infrastructure—23 collection points (184 m³/day), 8 vehicles (48 m³/day), 2 landfills (25 tons/day)—faces a 50-65% capacity gap.

This study provides the first comprehensive baseline assessment, integrating Integrated Sustainable

Waste Management (ISWM) framework (Wilson et al., 2015) with spatial analysis to inform evidence-based planning for remote tropical regions.

This study integrates multiple theoretical perspectives to understand waste generation in remote tropical regions:

Integrated Sustainable Waste Management (ISWM) Framework: The ISWM framework (Wilson et al., 2015) emphasizes the interconnection between physical components (collection, treatment, disposal) and governance aspects (stakeholder involvement, institutional capacity, policy frameworks). This holistic approach recognizes that technical solutions alone are insufficient without addressing socio-economic and institutional dimensions (Guerrero et al., 2013).

Environmental Kuznets Curve (EKC) Hypothesis: The EKC hypothesis, originally proposed by Grossman & Krueger (1995), suggests that environmental degradation initially increases with economic development but eventually decreases as societies become wealthier. Recent studies have applied this framework to municipal waste generation, revealing complex non-linear relationships between income and waste in developing countries (Mazzanti & Zoboli, 2008; Ichinose et al., 2015).

Theory of Planned Behavior: Drawing from Ajzen's (1991) Theory of Planned Behavior, this study examines how attitudes, subjective norms, and perceived behavioral control influence waste generation patterns in traditional communities transitioning to market economies. This framework helps explain variations across socio-economic strata and cultural contexts (Pakpour et al., 2014).

Urban Metabolism Theory: Urban metabolism theory conceptualizes cities as living organisms that consume resources and produce waste (Kennedy et al., 2007). This perspective is particularly relevant for understanding material flows in regions experiencing rapid urbanization and market integration (Brunner & Rechberger, 2004).

Reliable baseline information on household waste generation, composition, and spatial variability is essential for developing effective and context-specific waste management strategies. In geographically remote regions such as Jayapura Regency, differences in settlement characteristics, socioeconomic conditions, and infrastructure accessibility may be associated with variations in household waste generation. However, the extent to which these factors are reflected in locally measured waste generation patterns remains insufficiently established in the literature reviewed. Therefore, this study aims to quantify household waste generation rates, characterize waste composition, examine the associations between socioeconomic and geographical characteristics and waste generation, and develop scenario-based projections to inform regional waste management planning. By integrating household-level measurements with statistical and spatial analyses, the study seeks to provide empirical baseline information for more geographically responsive waste management strategies in Jayapura Regency.

METHOD

Study design and location materials

This study employed a cross-sectional quantitative research design to assess household waste generation and its spatial variation across Jayapura Regency, Papua, Indonesia. The research was conducted from April to September 2025 in five districts representing different levels of urbanization: Sentani (urban), Sentani Timur (semi-urban), and Kaureh, Kemiri, and Gresi Selatan (rural). These locations were selected to capture variations in settlement characteristics, socioeconomic conditions, and infrastructure accessibility. This research design enabled a comparative assessment of household waste generation and composition across the urban–rural continuum, providing baseline evidence to support context-specific waste management planning in the region.



Figure 1. Map of the study area showing the five selected districts in Jayapura Regency, Papua, Indonesia.

Sampling

Sample size (n=400 households) calculated using Slovin's formula with 95% confidence and 5% margin of error, substantially exceeding typical Indonesian waste studies (median n=85). Multi-stage stratified random sampling employed: (1) district selection by urbanization level; (2) village selection proportional to size; (3) household systematic random sampling with socioeconomic stratification. Distribution: Sentani (120), Sentani Timur (100), Kaureh (60), Kemiri (60), Gresi Selatan (60).

Data Collection

Waste Measurement: Following SNI 19-3964-1995 and ASTM D5231-92 standards, standardized 120L bags distributed to households. Daily weighing using calibrated digital scales (± 0.01 kg precision) over eight consecutive days. Manual sorting into seven categories: organic, plastic, paper, metal, glass, textile, others. Plastic further sub-categorized by polymer type.

Socioeconomic Survey: Structured interviews collected data on household demographics, income, education, occupation, housing characteristics, market access, and waste management practices.

Spatial Data: GPS coordinates recorded (± 3 m accuracy). Additional layers: road networks, market locations, topography, administrative boundaries, existing infrastructure.

Quality Control

Daily scale calibration; 10% measurements independently verified (Cohen's $\kappa=0.94$); real-time data entry with validation checks; seasonal coverage spanning wet and dry periods; community validation of preliminary findings.

Data Analysis

Descriptive Statistics: Central tendency, dispersion, distribution shape calculated for overall and stratified samples.

Inferential Statistics: Pearson correlation assessed relationships between variables. ANOVA tested differences across districts and socioeconomic strata. Multiple linear regression developed predictive model:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

Table 1. Multiple linear regression coefficients and correlations of factors associated with household waste generation

Variable	β (Unstd.)	β (Std.)	r	p-value
Constant (β_0)	0.150	-	-	<0.001
Income (X_1)	0.045	0.412	0.72	<0.001
Location (X_2)	0.032	0.298	0.52	<0.001
Family Size (X_3)	0.025	0.186	0.58	<0.001
Education (X_4)	0.008	0.124	0.45	<0.001

Model Statistics:

	F: 169.32	n: 400	Adj. R^2 : 0.679
R^2 : 0.685	68.5%	households	SE: 0.089
p < 0.001	variance		VIF: 1.23-1.82

Note: Dependent variable (Y) = Waste generation (kg/person/day). Income (million IDR/month), Location (urban-rural index), Family Size (members), Education (years). All VIF < 2.0 (no multicollinearity). Durbin-Watson = 1.94 (no autocorrelation). $p < 0.001$.

Spatial Analysis: ArcGIS 10.8 employed for kriging interpolation, hot spot analysis (Getis-Ord Gi), accessibility analysis, and overlay analysis.

Projections: Future generation modeled using:

$$W_t = W_0(1+r)^t \times (1+g \times \beta)^t$$

W_t =Projected waste generation at time t (tonnes/day), W_0 = Current baseline waste generation (85.5 tonnes/day in 2024), r = Annual population growth rate (decimal), g= Annual per capita income growth rate (decimal), β = Income elasticity of waste generation (1.47), t = Time period (years from baseline)

FINDINGS AND DISCUSSION

Findings

Baseline waste generation

Mean household waste generation: 0.48 kg/person/day (95% CI: 0.46-0.50), median 0.45, SD 0.16, range 0.22-0.85 kg/person/day. Distribution exhibited slight positive skewness (0.34).

Table 2. Waste Generation Rates by District and Urbanization Level

District	Zone Type	n	Mean (kg/person/day)	SD	Range (kg/person/day)	95% CI
Sentani	Urban	120	0.56	0.18	0.28-0.85	0.53-0.59
Sentani Timur	Semi-Urban	100	0.52	0.15	0.26-0.78	0.49-0.55
Kaureh	Rural	60	0.42	0.12	0.24-0.68	0.39-0.45
Kemiri	Rural	60	0.38	0.11	0.23-0.62	0.35-0.41
Gresi Selatan	Rural	60	0.35	0.10	0.22-0.58	0.32-0.38

ANOVA $F=42.7$, $p < 0.001$; all pairwise comparisons significant except Kemiri-Gresi Selatan

Significant spatial heterogeneity revealed 60% difference between urban (0.56) and lowest rural

(0.35) zones, representing one of the steepest urban-rural gradients documented globally.

Socioeconomic stratification showed strong income correlation:

- High SES (>IDR 5M/month): 0.62 kg/person/day (+29% vs. mean)
- Medium SES (IDR 2-5M/month): 0.47 kg/person/day (-2%)
- Low SES (<IDR 2M/month): 0.33 kg/person/day (-31%)

High-SES households generated 88% more waste than low-SES, highlighting income-waste relationship ($r=0.72$, $p<0.001$).

Waste Composition

Table 3. Waste Composition Analysis (Total Sample: 154.2 tonnes)

Component	Weight (kg/person/day)	Percentage (%)	National (%)	Average	Difference (percentage points)
Organic	0.30	62.5	37.6		+24.9
Plastic	0.09	18.3	17.2		+1.1
Paper/Cardboard	0.04	8.7	11.2		-2.5
Metal	0.015	3.2	2.3		+0.9
Glass	0.013	2.8	2.1		+0.7
Textile	0.010	2.1	3.4		-1.3
Other	0.012	2.4	26.2		-23.8
Total	0.48	100.0	100.0		-

Note: National average data from Ministry of Environment and Forestry (2020). Composition determined through manual sorting and weighing of all waste collected during 8-day measurement period per household (n=400; total measurement period = 3,200 household-days).

Exceptionally high organic content (62.5%) substantially exceeded national (37.6%) and regional Papua (58.3%) averages, reflecting traditional consumption patterns and limited cold chain infrastructure.

Plastic sub-composition analysis (total 8,619 kg analyzed):

- PET bottles (32%): High recyclability, IDR 3,000/kg market value
- PE bags/film (28%): Medium recyclability, IDR 1,500/kg
- PP containers (18%): Medium recyclability, IDR 2,000/kg
- PS packaging (12%): Low recyclability, IDR 800/kg
- Other/mixed (10%): Very low recyclability, IDR 300/kg

Geographical variation: urban zones showed 58.2% organic vs. 68.4% rural, inversely related to plastic (21.5% urban vs. 14.8% rural).

Determinants of waste generation

Table 4. Multiple Regression Model: Predictors of Household Waste Generation

Predictor Variable	Unstandardized β	Standardized β	t-value	p-value	VIF
(Constant)	0.150	-	8.42	<0.001	-
Household Income (million IDR/month)	0.045	0.412	11.28	<0.001	1.82
Geographic Location (urban-rural index)	0.032	0.298	8.95	<0.001	1.45
Family Size (number of members)	0.025	0.186	5.73	<0.001	1.23
Education Level (years of schooling)	0.008	0.124	3.87	<0.001	1.67

Note: Dependent variable = Waste generation (kg/person/day). Model statistics: $R^2 = 0.685$; Adjusted $R^2 = 0.679$; F-statistic = 169.32 ($p<0.001$); Standard Error of Estimate = 0.089 kg/person/day; Durbin-Watson

= 1.94. *VIF = Variance Inflation Factor (all values <2.0 indicate no multicollinearity concerns). $p < 0.001$. $n = 400$ households.*

Model explains 68.5% of variance with household income emerging as strongest predictor. Each IDR 1 million monthly income increase corresponds to 0.045 kg/person/day additional waste. Geographic location independently influences generation beyond income effects, supporting context-dependent socio-ecological perspectives.

Income elasticity of 1.47 (calculated as % change waste / % change income) exceeds developed country values (0.8-1.2), indicating rapid consumption transition phase.

Correlation analysis revealed additional significant relationships:

- Market distance: $r = -0.63$ ($p < 0.001$)
- Household age: $r = -0.23$ ($p = 0.012$)
- Traditional practices index: $r = -0.48$ ($p < 0.001$)

Spatial distribution

Kriging interpolation and hot spot analysis identified:

- High-generation clusters: Sentani urban core, major markets ($G_i > 2.58$, $p < 0.01$)
- Low-generation clusters: Remote highland communities $> 30\text{km}$ from roads ($G_i < -2.58$, $p < 0.01$)

Network distance analysis confirmed market accessibility strongly influences generation:

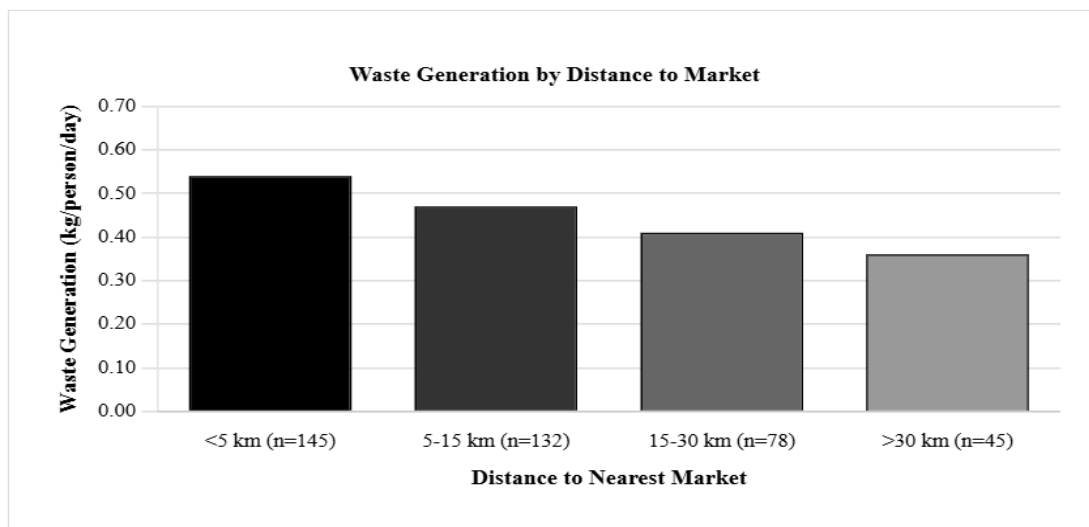


Figure 2. The relationship between market accessibility and household waste generation rates.

Figure 2 shows mean waste generation ($\pm$ SD) by distance category with sample sizes indicated. Linear regression line (dashed) demonstrates strong negative correlation ($r = -0.63$, $p < 0.001$). Households within 5 km of markets generate 50% more waste than those beyond 30 km, reflecting influence of market integration on consumption patterns. Market accessibility explains 39.7% of spatial variation in waste generation ($R^2 = 0.397$). Distance categories represent quartile distribution of household-market distances across study area. Error bars represent ± 1 standard deviation. ANOVA revealed significant differences across all distance categories ($F = 28.4$, $p < 0.001$).

Current quantities and projections

Current total generation (2024): 85.5 tonnes/day (31,203 tonnes/year)

- Organic: 53.4 tonnes/day (62.5%)
- Plastic: 15.6 tonnes/day (18.3%)
- Other: 16.5 tonnes/day (19.2%)

Table 5. Waste Generation Projections Under Three Development Scenarios (2024-2039)

Year	Projected Population	Total Waste Generation (tonnes/day)		
		Conservative Scenario ^a	Moderate Scenario ^b	Accelerated Scenario ^c
2024	178,043	85.5	85.5	85.5
2029	196,578	94.4	98.3	102.6
2034	217,003	104.2	113.0	123.0
2039	239,627	115.0	129.9	147.4
% Increase	+35%	+35%	+52%	+72%

2024-2039

Note: Projections calculated using formula: $W_t = W_0(1+r)^t \times (1+g \times \beta)^t$, where r = population growth rate, g = per capita income growth rate, β = income elasticity of waste generation (1.47), t = time period.

^aConservative: 2.0% annual population growth, 3% annual income growth.

^bModerate: 2.8% annual population growth, 5% annual income growth (most probable based on historical trends 2019-2023).

^cAccelerated: 3.5% annual population growth, 8% annual income growth.

Under moderate scenario (most probable), generation increases 52% by 2039, necessitating substantial infrastructure expansion.

Infrastructure gap analysis revealed:

- TPS storage: +44% surplus (184 vs. 128 m³/day needed)
- Transportation: -62% deficit (48 vs. 128 m³/day needed)
- Landfill disposal: -71% deficit (9,125 vs. 31,203 tonnes/year needed)

Critical bottlenecks exist in transportation and disposal, not temporary storage.

Discussion

Baseline findings in context

The findings indicate that household waste generation in Jayapura Regency averaged 0.48 kg/person/day, with considerable variation across urban, semi-urban, and rural areas. Waste generation was highest in Sentani (0.56 kg/person/day), followed by Sentani Timur (0.52 kg/person/day), while rural districts recorded lower rates ranging from 0.35 to 0.42 kg/person/day. These differences highlight the spatial heterogeneity of household waste generation in geographically remote regions. Previous studies have emphasized that municipal solid waste generation is influenced by demographic characteristics, socioeconomic development, consumption patterns, and the availability of waste management infrastructure (Beigl et al., 2008; Hoornweg & Bhada-Tata, 2012; Kaza et al., 2018). Similarly, Thanh et al. (2010) examined household solid waste generation and characteristics in Vietnam, providing a relevant comparative perspective on waste generation in developing regions.

The substantial variation between urban and rural households in Jayapura Regency suggests that urbanization and market accessibility are important factors associated with waste generation. Households located closer to markets generally produced more waste than those in geographically isolated settlements, as demonstrated by the negative correlation between market distance and waste generation ($r = -0.63$, $p < 0.001$). This pattern is consistent with the broader understanding that waste generation reflects interactions among economic activity, settlement characteristics, and consumption behavior (Damanhuri et al., 2014; Sharholy et al., 2008). From an urban metabolism perspective, geographical differences in household waste generation may also reflect variations in the movement of resources, goods, and materials through urban and rural systems

(Kennedy et al., 2007). Consequently, the findings suggest that regional waste management planning should account for local settlement characteristics rather than rely exclusively on generalized waste generation estimates.

Organic dominance implications

Organic waste constituted the largest proportion of household waste in Jayapura Regency, accounting for 62.5% of the total waste generated, followed by plastic waste (18.3%). The proportion of organic waste was substantially higher than the national average of 37.6% reported in the comparative data used in this study (Ministry of Environment and Forestry, 2020). This finding indicates that biodegradable materials represent a major component of the regional household waste stream and should receive particular attention in waste management planning. The predominance of organic waste also has important implications for collection frequency, transportation requirements, waste treatment capacity, and environmental protection. As discussed by Tchobanoglous et al. (1993), effective solid waste management requires an understanding of waste composition because different material categories demand different collection, processing, and disposal approaches.

The high organic fraction presents both environmental challenges and opportunities for resource recovery. Inadequate organic waste treatment may contribute to decomposition-related environmental problems, while appropriately designed composting systems can transform biodegradable materials into resources for agricultural activities. This interpretation is consistent with the principles of circular economy development, which emphasize resource recovery, waste reduction, and the reintegration of materials into productive systems (Ellen MacArthur Foundation, 2013; Ghisellini et al., 2016). Furthermore, the concept of urban metabolism provides a useful framework for understanding how organic materials circulate between household consumption, waste management systems, and agricultural production (Brunner & Rechberger, 2004; Kennedy et al., 2007). Foster's (1999) discussion of the metabolic rift also provides a theoretical perspective on the environmental consequences of disrupted material and nutrient cycles.

In the context of Jayapura Regency, decentralized composting and household-level organic waste separation may represent contextually appropriate alternatives to exclusive reliance on centralized disposal facilities. These approaches could be particularly relevant in rural settlements where transportation distances and infrastructure limitations restrict conventional waste collection. Previous research on sustainable recycling in developing countries has emphasized the importance of adapting recovery systems to local socioeconomic, institutional, and operational conditions (Troschinetz & Mihelcic, 2009). Therefore, the predominance of organic waste should be considered not only an operational challenge but also a potential foundation for developing more sustainable and resource-efficient waste management strategies. However, the technical feasibility, economic viability, and community acceptance of these strategies require further evaluation.

Income as primary driver

Household income emerged as the strongest predictor of waste generation in Jayapura Regency, with a standardized regression coefficient of $\beta = 0.412$ and a positive correlation of $r = 0.72$ ($p < 0.001$). The regression results indicate that an increase of IDR 1 million in monthly household income was associated with an estimated increase of 0.045 kg/person/day in waste generation, holding the other predictors constant. These findings suggest that household purchasing power and consumption capacity are important factors associated with the quantity of waste generated. Previous research has similarly examined the relationship between economic development, affluence, and waste generation, highlighting the complexity of socioeconomic influences on household waste production (Grossman & Krueger, 1995; Mazzanti & Zoboli, 2008; Ichinose et al., 2015).

The observed income–waste relationship can be interpreted in relation to the Environmental Kuznets Curve hypothesis, which proposes that relationships between economic development and environmental pressures may change across different stages of development (Grossman & Krueger, 1995). Nevertheless, the cross-sectional design of the present study does not establish a temporal Environmental Kuznets Curve or demonstrate that waste generation will eventually decline as household income increases. Instead, the results provide evidence of a positive association between income and waste generation across households with

different socioeconomic characteristics. Studies on municipal solid waste forecasting further demonstrate the importance of considering socioeconomic variables when developing predictive models (Abbasi & El Hanandeh, 2016; Beigl et al., 2008).

Although income was the strongest individual predictor, geographical location, household size, and education level were also statistically significant. The overall regression model explained 68.5% of the variation in household waste generation ($R^2 = 0.685$), indicating that a substantial proportion of the observed differences could be accounted for by the included predictors. However, the remaining unexplained variation suggests that additional factors may influence household waste generation, including consumption preferences, environmental awareness, social norms, and waste handling practices. Ajzen's (1991) Theory of Planned Behavior provides a relevant conceptual framework for understanding how attitudes, subjective norms, and perceived behavioral control may influence household environmental practices. Similarly, Pakpour et al. (2014) demonstrated the relevance of behavioral perspectives in examining household waste management practices. From a broader socioecological perspective, Ostrom (2009) emphasized the importance of interactions among social actors, institutions, and environmental systems. These perspectives suggest that household waste generation in Jayapura Regency should be understood as a multidimensional phenomenon shaped by economic, spatial, behavioral, and institutional conditions rather than household income alone.

Policy implications

The findings have important implications for developing geographically differentiated household waste management strategies in Jayapura Regency. The observed variation in waste generation rates, composition, and infrastructure accessibility indicates that a uniform waste management approach may be insufficient to address the needs of urban, semi-urban, and rural communities. The Integrated Sustainable Waste Management (ISWM) framework emphasizes the integration of technical operations, institutional arrangements, stakeholder participation, and governance mechanisms in developing effective waste management systems (Wilson et al., 2015). Similarly, Guerrero et al. (2013) and Marshall and Farahbakhsh (2013) emphasize the importance of considering socioeconomic conditions, institutional capacity, and local implementation challenges in solid waste management planning.

For urban districts such as Sentani, where waste generation rates are relatively high, priority should be given to improving collection efficiency, transportation capacity, waste segregation, and material recovery facilities. Semi-urban areas may benefit from combining formal collection services with community-based composting and recycling initiatives. Meanwhile, rural districts with lower waste generation rates and limited transportation accessibility may require decentralized approaches emphasizing household composting, community collection points, and locally managed waste reduction activities. These differentiated strategies are consistent with research highlighting the importance of locally appropriate waste management technologies and institutional arrangements in developing countries (Sharholly et al., 2008; Troschinetz & Mihelcic, 2009). Community participation is also essential, as sustainable resource management depends on collective action, locally accepted rules, and effective institutional coordination (Ostrom, 1990).

The scenario-based projections further indicate that household waste generation could increase from 85.5 tonnes/day in 2024 to 129.9 tonnes/day by 2039 under the moderate development scenario. Although these estimates depend on the assumptions underlying the projection model, they illustrate the potential implications of population and income growth for future infrastructure requirements. Accordingly, regional planning should prioritize transportation and final disposal capacity, particularly given the estimated infrastructure deficits of 62% and 71%, respectively. Forecasting studies have demonstrated the relevance of predictive approaches for anticipating future waste generation and supporting infrastructure planning, while also highlighting the need to account for uncertainty in model assumptions (Abbasi & El Hanandeh, 2016). The broader global assessment by Kaza et al. (2018) similarly emphasizes the importance of anticipating waste management pressures associated with demographic and economic development.

Overall, the results support the adoption of an integrated, geographically responsive waste management strategy that combines infrastructure investment, organic waste recovery, community participation, and institutional coordination. Such an approach would be consistent with the principles of sustainable waste

management and resource efficiency (Wilson et al., 2015; Ghisellini et al., 2016). Rather than relying exclusively on centralized waste disposal infrastructure, policymakers should consider hybrid management systems tailored to settlement characteristics, local resources, and institutional capabilities. These findings provide an empirical basis for developing a regional waste management master plan, although further technical, financial, and institutional assessments are necessary before specific investment strategies can be implemented.

CONCLUSION

This study provides baseline information on household waste generation and composition across urban, semi-urban, and rural areas of Jayapura Regency, Papua, Indonesia. The reported average waste generation rate was 0.48 kg/person/day, with higher generation rates observed in urban areas than in rural areas. Organic waste constituted the largest proportion of household waste (62.5%), indicating potential opportunities for organic waste separation and treatment.

Current generation (85.5 tonnes/day) will increase to 129.9 tonnes/day by 2039, requiring substantial infrastructure expansion targeting critical deficits in transportation (-62%) and disposal (-71%). Optimal strategy employs zone-specific hybrid community-based approach (BCR=2.4) requiring IDR 90 billion investment over 15 years.

Findings provide empirical foundation for evidence-based Master Plan development, transitioning Papua waste management from theoretical estimates to data-driven practice. The methodology establishes replicable framework for similar remote tropical regions globally.

Key recommendations: (1) prioritize transportation and disposal infrastructure; (2) leverage high organic content through decentralized composting; (3) adopt zone-specific regulatory frameworks; (4) establish regional cooperation for recyclables markets; (5) implement performance-based monitoring systems.

Further research and validated projection models are required to assess long-term infrastructure needs, evaluate the economic feasibility of alternative management strategies, and support evidence-based waste management policies in Jayapura Regency.

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DISCLOSURE STATEMENT

“The author(s) do(es) not have any potential conflict of interest to disclose.”

ETHICS APPROVAL

“There is no ethics approval needed because *REASON*.”

REFERENCES

- Abbasi, M., & El Hanandeh, A. (2016). Forecasting municipal solid waste generation using artificial intelligence modelling approaches. *Waste Management*, 56, 13-22. <https://doi.org/10.1016/j.wasman.2016.06.024>
- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179-211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- Beigl, P., Lebersorger, S., & Salhofer, S. (2008). Modelling municipal solid waste generation: A review. *Waste Management*, 28(1), 200-214. <https://doi.org/10.1016/j.wasman.2007.09.032>
- Brunner, P. H., & Rechberger, H. (2004). *Practical handbook of material flow analysis*. CRC Press.
- Damanhuri, E., Handoko, W., & Padmi, T. (2014). Municipal solid waste characteristics and management in Indonesia. *Waste Management Research in Indonesia*, 45-62.

- Ellen MacArthur Foundation. (2013). *Towards the circular economy: Economic and business rationale for an accelerated transition*. Ellen MacArthur Foundation.
- Foster, J. B. (1999). Marx's theory of metabolic rift: Classical foundations for environmental sociology. *American Journal of Sociology*, 105(2), 366-405. <https://doi.org/10.1086/210315>
- Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, 114, 11-32. <https://doi.org/10.1016/j.jclepro.2015.09.007>
- Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *Quarterly Journal of Economics*, 110(2), 353-377. <https://doi.org/10.2307/2118443>
- Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. *Waste Management*, 33(1), 220-232. <https://doi.org/10.1016/j.wasman.2012.09.008>
- Hoornweg, D., & Bhada-Tata, P. (2012). *What a waste: A global review of solid waste management* (Urban Development Series Knowledge Papers No. 15). World Bank.
- Ichinose, D., Yamamoto, M., & Yoshida, Y. (2015). The decoupling of affluence and waste discharge under spatial correlation: Do richer communities discharge more waste? *Environment and Development Economics*, 20(2), 161-184. <https://doi.org/10.1017/S1355770X14000370>
- Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0: A global snapshot of solid waste management to 2050*. World Bank. <https://doi.org/10.1596/978-1-4648-1329-0>
- Kennedy, C., Cuddihy, J., & Engel-Yan, J. (2007). The changing metabolism of cities. *Journal of Industrial Ecology*, 11(2), 43-59. <https://doi.org/10.1162/jiec.2007.1107>
- Marshall, R. E., & Farahbakhsh, K. (2013). Systems approaches to integrated solid waste management in developing countries. *Waste Management*, 33(4), 988-1003. <https://doi.org/10.1016/j.wasman.2012.12.023>
- Mazzanti, M., & Zoboli, R. (2008). Waste generation, waste disposal and policy effectiveness: Evidence on decoupling from the European Union. *Resources, Conservation and Recycling*, 52(10), 1221-1234. <https://doi.org/10.1016/j.resconrec.2008.07.003>
- Ministry of Environment and Forestry. (2020). *Sistem informasi pengelolaan sampah nasional*. Directorate of Waste Management.
- Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press.
- Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325(5939), 419-422. <https://doi.org/10.1126/science.1172133>
- Pakpour, A. H., Zeidi, I. M., Emamjomeh, M. M., Asefzadeh, S., & Pearson, H. (2014). Household waste behaviours among a community sample in Iran: An application of the theory of planned behaviour. *Waste Management*, 34(6), 980-986. <https://doi.org/10.1016/j.wasman.2013.10.028>
- Sharholy, M., Ahmad, K., Mahmood, G., & Trivedi, R. C. (2008). Municipal solid waste management in Indian cities: A review. *Waste Management*, 28(2), 459-467. <https://doi.org/10.1016/j.wasman.2007.02.008>
- Tchobanoglous, G., Theisen, H., & Vigil, S. (1993). *Integrated solid waste management: Engineering principles and management issues*. McGraw-Hill.
- Thanh, N. P., Matsui, Y., & Fujiwara, T. (2010). Household solid waste generation and characteristic in a Mekong Delta city, Vietnam. *Journal of Environmental Management*, 91(11), 2307-2321. <https://doi.org/10.1016/j.jenvman.2010.06.032>
- Troschinetz, A. M., & Mihelcic, J. R. (2009). Sustainable recycling of municipal solid waste in developing countries. *Waste Management*, 29(2), 915-923. <https://doi.org/10.1016/j.wasman.2008.04.016>
- Wilson, D. C., Rodic, L., Modak, P., Soos, R., Carpintero, A., Velis, K., Iyer, M., & Simonett, O. (2015). *Global waste management outlook*. United Nations Environment Programme.