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From Waste to Resource: A SWOT Evaluation of Organic Waste Composting for Sustainable Waste Management in Cameron Highlands

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Organic waste management presents a critical environmental challenge in highland agricultural and tourism regions such as Cameron Highlands, Malaysia. This study evaluates the environmental performance of organic waste composting initiatives introduced under the Cameron Highlands Green Initiative, using a SWOT (Strengths, Weaknesses, Opportunities, Threats) analytical framework. Data were collected through structured surveys, field observations, and secondary data from 2019 to 2024. The findings reveal key strengths including reduced landfill dependency, greenhouse gas mitigation, and enhanced soil health through compost application. However, the study also identifies infrastructure limitations, inconsistent compost quality, and limited technical capacity among operators as major weaknesses. Opportunities were found in policy incentives, organic market expansion, and community partnerships, while threats included climate variability, market competition from chemical fertilizers, and community resistance. The study concludes with strategic recommendations to enhance composting adoption, including capacity-building programs, infrastructure upgrades, and supportive policy integration. These insights contribute to the development of low-carbon, circular economy strategies for sustainable waste management in highland areas.

1. Introduction

The Cameron Highlands region in Pahang, Malaysia, is not only an agriculturally rich and ecotourism-driven area but also a focal point for the country's horticultural output. However, the intensification of agricultural production and hospitality services has led to significant organic waste generation, predominantly from vegetable farms and hotel food waste (Mansha et al., 2025). According to the Ministry of Housing and Local Government (KPKT), an estimated 30 t of organic waste are disposed of daily, predominantly via landfilling and incineration methods that contribute substantially to greenhouse gas (GHG) emissions (Adiansyah 2022) and environmental degradation (Abdul Ghafar and Bghdadi 2025). Global and regional studies have shown the potential of composting as a sustainable waste management strategy. For example, Ahmed et al. (2019) emphasized the role of composting in nutrient recovery, while Ansar et al. (2025) discussed composting's economic feasibility in biodegradable waste management. A recent environmental life cycle assessment of a decentralized composting approach in Dhaka estimated total yearly GWP_{100} emissions from windrow composting at 1.14 M kg CO_2-eq per Mg processed, much lower than landfill scenarios (Ashraf et al., 2025). However, in Malaysia, particularly in highland regions like Cameron Highlands, there is limited research that holistically assesses composting from environmental, socio-economic, and strategic perspectives (Ansar et al., 2025). This study fills that gap by applying a SWOT (Strengths, Weaknesses, Opportunities, Threats) analytical framework to evaluate composting practices under the Cameron Highlands Green Initiative. By combining stakeholder perceptions, field observations, and quantitative indicators, this study aims to (i) identify internal

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strengths and weaknesses of composting initiatives, (ii) explore external opportunities and threats, and (iii) offer strategic insights for policy, practice, and scalability in sustainable waste management.

2. Methodology

2.1 Study Area and Context

This study was conducted in Cameron Highlands, Pahang, Malaysia, an agriculturally intensive and ecologically sensitive highland region. Known for its rich biodiversity, and economic reliance on vegetable cultivation and eco-tourism, the area faces a growing challenge in managing escalating volumes of organic waste. The region generates approximately 800 metric t of vegetable produce daily, with around 30 t of residual organic waste entering the solid waste stream (Firdaus et al., 2024). However, waste management infrastructure remains limited, comprising only one sanitary landfill and a single incinerator plant, both of which operate under constrained capacity.

Due to the lack of effective waste segregation, a substantial portion of organic waste is either incinerated or disposed of in landfills, contributing to GHG emissions, soil and water contamination, and ecological degradation. In light of these issues, Cameron Highlands presents a pertinent case study for evaluating the environmental performance of composting as a sustainable waste management strategy. The study area included municipal markets, agricultural zones, composting facilities, and hospitality businesses involved in the Cameron Highlands Green Initiative.

2.2 Research Design and Data Collection

This study employed a mixed-methods research design, integrating both qualitative and quantitative approaches to enable a holistic understanding of the strengths, weaknesses, opportunities, and threats associated with organic waste composting. The conceptual framework of the study is outlined in Figure 1.

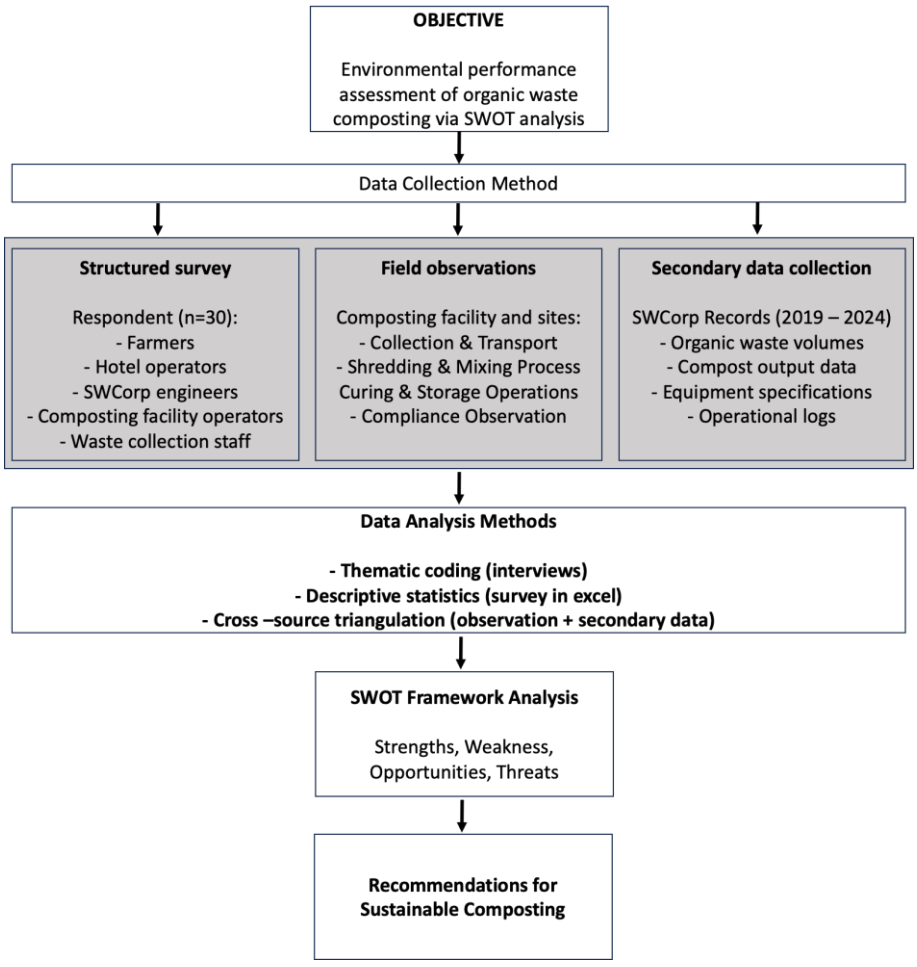

Figure 1: Conceptual framework of the study

The methods consist of structured surveys that evaluate awareness and adoption levels, field observations at composting and disposal sites, and secondary data collected from Solid Waste Management and Public Cleansing Corporation (SWCorp) Malaysia (2019–2024). These methods are conducted with a diverse range of stakeholders, including farmers, hotel operators, engineers, and compost workers. These data streams were triangulated and analysed using descriptive statistics and thematic coding, resulting in a SWOT analysis that synthesises the internal and external factors that influence the effectiveness of decomposition. Evidence-based recommendations for sustainable waste management in highland agricultural regions are informed by the framework, which emphasises a comprehensive, multi-stakeholder evaluation pathway.

2.3 SWOT Analysis

Data from surveys, field observations, and secondary sources were categorised into four SWOT domains: strengths (e.g., composting benefits, stakeholder support), weaknesses (e.g., infrastructural limitations, technical knowledge gaps), opportunities (e.g., favourable policies, rising market demand), and threats (e.g., climate variability, fertiliser competition). Data triangulation and thematic classification ensured consistency and depth (Santos et al., 2020). Key performance indicators (Table 1) were derived from Likert-scale survey responses and project data, including awareness levels, adoption rates, satisfaction scores, reported challenges, and estimated environmental impact. SWOT indicators were defined using stakeholder feedback, field observations, and secondary data, guided by established literature. Strengths included: environmental impact (waste diversion, GHG reduction) (Aich and Ghosh, 2016), soil health and agriculture (crop yield and soil structure improvement) (Hargreaves et al., 2008), stakeholder support (institutional backing, partnerships) (Wilson et al., 2012), circular economy integration (alignment with SDGs 11, 12, 13) (Kirchherr et al., 2017), and tourism synergy (eco-tourism branding) (Gössling, 2018). Weaknesses were operational or adoption constraints such as infrastructure, quality, skills, nuisance factors, and sectoral gaps (Iacovidou and Zorpas, 2022). Opportunities included policy support, market potential, innovation, education, and partnerships (Papadopoulou et al., 2025). Threats included climatic variability, market competition, community opposition, and policy inconsistency (Papadopoulou et al., 2025). These definitions ensured qualitative themes in the results were grounded in established concepts and empirical evidence.

Table 1: Key performance indicators and calculation methods used in the SWOT analysis

Metric	Description	Calculation Method
Awareness Level (%)	Percentage aware of composting benefits	% scoring ≥4 on 5-point Likert scale
Adoption Rate (%)	Stakeholders practising composting	(Yes responses / total group) × 100
Satisfaction Score (1–5)	Perceived effectiveness of composting	Mean score from satisfaction question
Challenges (%)	Proportion reporting at least one challenge	(Challenges reported / total group) × 100
Environmental Impact (%)	Estimated waste reduction attributed to composting	Based on stakeholder estimation and SWCorp data

3. Results and Discussion

3.1 Organic Waste Management Practices in Cameron Highlands

Cameron Highlands' organic waste management landscape is characterized by a combination of conventional and emerging practices. Landfilling remains the predominant disposal method, with approximately 90–95 % of municipal solid waste being dumped in the Blue Valley sanitary landfill or treated through incineration. Composting, although increasingly promoted through the Cameron Highlands Green Initiative, still occupies a minor share of total waste treatment. Field observations revealed that waste collection is managed by a government-appointed concessionaire (Alam Flora Sdn. Bhd.), which collects vegetable waste from markets and hospitality premises. These wastes are then transported to a centralised composting facility. The composting process includes mechanical shredding of feedstock (20–50 mm), adjustment of carbon-to-nitrogen ratio (25–30:1) and moisture (50–60 %), and microbial inoculation. Aerated in-vessel composting units maintain 55–65 °C for ≥3 days to ensure pathogen reduction, with oxygen >10% through controlled aeration. After 3–4 weeks of curing, compost is sieved and tested for moisture, pH, and nutrients before distribution. The output is either wet or dry compost, distributed to farmers and used for landscaping by hotels. Despite infrastructural efforts, organic waste is often mixed with other municipal solid waste due to inadequate segregation at source (Harun et al., 2025). This compromises compost quality and reduces efficiency. Additionally, the incinerator operates below capacity due to high maintenance costs, limited technical expertise, and operational

inefficiencies. Stakeholder responses underscored a consensus on the environmental value of composting but highlighted numerous implementation barriers, including insufficient training, logistical limitations, and public scepticism towards composting efficacy.

3.2 SWOT Analysis of Organic Waste Composting

3.2.1 Strengths

The primary strengths identified through stakeholder input and field data include:

- Environmental Impact: Composting has significantly reduced landfill dependency and mitigated methane emissions. From 2019 to 2024, over 1.14 M kg of organic waste was diverted from landfills, preventing substantial GHG emissions.
- Soil Health and Agriculture: Farmers reported improved crop performance and soil structure following compost application. Nutrient-rich compost serves as a low-cost alternative to synthetic fertilisers.
- Stakeholder Support: Government backing through SWCorp, along with partnerships with local Non-Profit Organization (NGO) and Japan International Cooperation Agency (JICA), has led to increased access to composting machines and technical advice.
- Circular Economy Integration: The composting initiative supports Malaysia's circular economy goals, aligning with SDGs 11, 12, and 13.
- Tourism Synergy: Composting contributes positively to Cameron Highlands' branding as a sustainable eco-tourism destination.

3.2.2 Weaknesses

Despite these strengths, several internal limitations constrain widespread adoption:

- Infrastructure Limitations: The region has only one composting centre with limited processing capacity and insufficient logistics to support broader waste collection.
- Compost Quality Variability: Due to a lack of standardisation and inconsistent waste input, compost quality varies significantly, affecting user confidence.
- Technical Knowledge Gaps: Farmers and facility operators often lack the expertise required for optimal composting practices, leading to process inefficiencies.
- Odour and Pest Concerns: Improper handling of feedstock results in odour issues and pest attraction, particularly near residential zones.
- Low Participation from Certain Sectors: Hotels and commercial premises exhibit lower adoption due to logistical barriers and low awareness.

To address these weaknesses, several measures can be undertaken. Infrastructure limitations could be reduced by establishing decentralised composting hubs and improving waste collection logistics. Compost quality variability can be mitigated through standardised operating procedures and improved source segregation at collection points. Technical knowledge gaps should be addressed with targeted training programs for farmers and facility operators. Odour and pest concerns can be minimised through appropriate pre-treatment, aeration control, and regular monitoring. Low participation from certain sectors, particularly hotels and commercial premises, can be improved through awareness campaigns, incentive schemes, and partnership models with local councils.

3.2.3 Opportunities

External conditions provide several avenues for improving and scaling composting practices:

- Policy and Regulatory Incentives: Government targets to divert 40 % of waste from landfills by 2030 provide a favourable policy environment. Tax exemptions and grants for composting infrastructure further enhance feasibility.
- Market Demand for Organic Products: The growing local and international demand for organic produce creates a strong commercial incentive for compost adoption.
- Technological Innovations: Advances in smart composting systems and biochar-enhanced compost can improve efficiency, scalability, and product consistency.
- Educational Campaigns: Awareness programs, particularly in schools and local councils, have the potential to mainstream composting practices across multiple sectors.
- Stakeholder Partnerships: SWCorp's collaboration with the Malaysian Hotel Association and Farmers' Associations illustrates the viability of multi-actor coalitions.

3.2.4 Threats

Several external threats may undermine the long-term sustainability of composting initiatives:

- Climate Variability: Excessive rainfall and humidity in Cameron Highlands can disrupt aerobic composting conditions, leading to poor-quality outputs and pathogen proliferation.
- Market Competition: Chemical fertilisers remain cheaper and more accessible, limiting compost's market penetration without sufficient government subsidies or awareness campaigns.
- Community Resistance: Residents near composting sites sometimes oppose facilities due to perceived health risks or odour nuisances.
- Policy Inconsistencies and Enforcement Gaps: While supportive frameworks exist, inconsistent enforcement and lack of local government engagement weaken the implementation of national targets.

3.3 Comparative Stakeholder Perceptions: Matrix Analysis

A matrix analysis comparing stakeholder perceptions revealed key differences in awareness, adoption, satisfaction, and perceived environmental impact (Table 2). The results indicate that awareness and satisfaction are highest among technical stakeholders (engineers, compost operators), while hotel operators and concession workers report the greatest challenges. These findings suggest the need for tailored outreach, infrastructure support, and role-specific training.

Table 2: Comparative matrix of stakeholder perceptions on composting awareness, adoption, satisfaction, operational challenges, and environmental impact in Cameron Highlands

Stakeholder Group	Awareness (%)	Adoption (%)	Satisfaction (1–5)	Challenges (%)	Perceived Impact (%)
Farmers (n = 21)	85 %	65 %	4.2	70 %	50 %
Hotel Operators (n = 3)	60 %	40 %	3.8	80 %	45 %
SWCorp Engineers (n = 1)	100 %	100 %	5.0	30 %	60 %
Compost Operators (n = 1)	90 %	100 %	4.5	50 %	55 %
Collection Workers (n = 4)	75 %	50 %	3.5	85 %	40 %

3.4 Synthesis and Strategic Implications

The SWOT analysis affirms that composting holds substantial promise for advancing sustainable waste management in Cameron Highlands. However, the transition from pilot initiatives to systemic integration requires strategic interventions. Key leverage points include:

- Policy Integration: Composting should be embedded into local waste management plans and supported through municipal ordinances and procurement policies.
- Capacity Building: Training modules and technical assistance programs are needed for both compost operators and waste generators (e.g., farmers, hoteliers).
- Public Participation: Community-based composting hubs and school education programs can enhance local ownership and reduce resistance.
- Economic Incentives: Establishing a subsidy scheme or compost procurement policy can strengthen market uptake and support producers.

Ultimately, the success of composting in Cameron Highlands depends on an integrated, cross-sectoral approach, one that combines technical innovation, behavioural change, regulatory support, and inclusive stakeholder engagement.

4. Conclusion and Recommendations

The SWOT framework highlighted key strengths, gaps, and strategic priorities, showing that with strong governance, coherent policies, and targeted capacity building, composting can be central to Malaysia's low-carbon, circular economy transition, especially in highland regions with intensive agriculture and sensitive ecosystems. To strengthen and expand composting in Cameron Highlands, several strategic actions are recommended. First, infrastructure and logistics must be improved by establishing decentralised composting hubs, upgrading existing facilities with smart technologies, and enhancing source segregation systems. Second, technical capacity should be built through stakeholder-specific training, development of standard operating procedures, and the promotion of peer-to-peer knowledge sharing. Third, supportive policy mechanisms are essential, including mandatory organic waste separation, composting targets in local plans, and financial incentives such as subsidies or tax relief. Fourth, compost product quality should be standardised through certification, while market demand can be stimulated by integrating compost use into public sector procurement and creating farmer-led compost cooperatives. Fifth, public awareness must be increased through education campaigns, school programs, and community engagement. Finally, composting should be integrated into broader sustainability efforts, including national climate and biodiversity strategies, public-private partnerships,

and GHG emissions tracking through life cycle assessments. This initiative achieved 1.14 M kg waste diversion, ~1,767 t CO_2-e reduction, adoption rates of 65% (farmers) and 40% (hotels), and high satisfaction scores (4.2/5 and 3.8/5). The model is scalable to other highland and peri-urban regions in Malaysia and Southeast Asia.
Future studies should explore practical measures to address these weaknesses include expanding infrastructure through decentralised hubs, standardising compost quality, providing targeted technical training, and improving participation via awareness campaigns and incentives. Behavioural research is also needed to understand public attitudes and motivations toward composting participation. Additionally, modelling the scalability of decentralised composting systems in highland and rural contexts would provide valuable insights for policy and infrastructure planning. Addressing these gaps will help refine composting strategies and support more resilient, climate-aligned waste management systems.

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