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Preliminary Insights into Sustainable Management of Coconut Waste from Smallholders in Bagan Datuk, Malaysia

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ABSTRACT. The improper disposal of coconut waste poses significant environmental and economic challenges, particularly among smallholders in Bagan Datuk, Perak. This study investigates smallholders' perspectives on sustainable coconut waste management, incorporating the Theory of Planned Behaviour (TPB) to analyse key behavioural determinants. A total of 30 smallholders were selected through simple random sampling to ensure a representative sample. The reliability analysis confirmed the robustness of the survey instrument, with a Cronbach's alpha value of 0.938, indicating high internal consistency. Findings reveal that while smallholders exhibit strong awareness and positive attitudes toward sustainable waste management, several barriers hinder adoption, including financial constraints, technological limitations, and time constraints. The study identifies viable waste processing technologies, such as composting and upcycle products which align with local resource availability and economic feasibility. Furthermore, the environmental consequences of improper disposal, such as methane emissions and soil degradation, underscore the urgency of implementing effective waste management strategies. Policy recommendations include financial incentives, capacity-building programmes, and enhanced stakeholder engagement to support smallholder adoption of sustainable practices. This study provides critical insights for policymakers, researchers, and industry stakeholders seeking to improve coconut waste valorisation and promote sustainability in smallholder agriculture.

Key words: Sustainable Management, Coconut Waste, Coconut Farm, Smallholders, Bagan Datuk

INTRODUCTION

The coconut (*Cocos nucifera L.*), a key member of the palm family (*Arecaceae*), is highly valued for its versatility and diverse applications. Coconut palms can grow up to 30 meters tall, with pinnate leaves spanning 60 to 90 cm in length (Man & Shah, 2020; Omar et al., 2023). Known as the "*Tree of Life*" due to its wide range of uses, the coconut palm thrives as a perennial crop in tropical and subtropical regions such as India, the Philippines, Malaysia, Sri Lanka, and the Indian Ocean (Beveridge et al., 2022; Rojas-Sandoval & Acevedo-Rodríguez, 2022). It is cultivated in over 90 countries, predominantly in Asia and the Pacific (Man & Shah, 2020). The coconut fruit is a fibrous drupe composed of five main parts: the solid endosperm (coconut meat or kernel) and liquid endosperm (coconut water), both edible, and three protective layers surrounding the seed called the endocarp (hard inner shell), mesocarp (thick husk), and exocarp (outer shell) (Vieira et al., 2024). Coconut meat is the most utilized component of the fruit, but every part of the plant, from the stems to the husks and shells, can be transformed into value-added products and byproducts (Lin et al., 2023).

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In Malaysia, the coconut industry is divided into estates or plantations and smallholder farms. Smallholders account for over 90% of coconut farms, typically managing landholdings of less than one hectare (Omar et al., 2023; Omar & Fatah, 2021). These smallholder farms are found across Peninsular Malaysia, Sabah, and Sarawak, involving around 90,000 to 100,000 farmers. Malaysia produces roughly 555,120 tonnes of coconuts annually, ranking among the top 10 global producers. Coconut is Malaysia's fourth most important industrial crop, following oil palm, rice, and rubber. Malaysia's coconut production rose from 550,140 tonnes in 2010 to 624,152 tonnes in 2013 (Omar & Fatah, 2021). However, despite government initiatives to enhance production and meet growing demand, Malaysia's global ranking dropped from 10th in 2010 to 11th by 2015, with an output of 0.055 metric tonnes in 2010 (Man & Shah, 2020). Coconut waste holds significant potential in advancing a circular economy by providing opportunities to repurpose waste and enhance resource efficiency (Muriuki et al., 2024). By incorporating this waste into practices such as recycling and upcycling, waste generation can be minimized, and valuable products can be created (Beveridge et al., 2022; Rojas-Sandoval & Acevedo-Rodríguez, 2022). This approach not only drives economic growth and generates employment but also supports environmental conservation by reducing carbon footprints and promoting sustainable alternatives to traditional materials (Das et al., 2022). Integrating coconut residues into a circular economy framework encourages sustainable development and adopts a regenerative approach to managing resources effectively.

Sustainable Management in Coconut Waste

With proper planning, agricultural waste management can significantly benefit production industries while optimising resource utilisation (Sarkar et al., 2021). In Malaysia, crop waste management has become a pressing issue, with approximately 1.2 million tonnes of agricultural waste disposed of annually due to the rapid expansion of the agricultural sector. This waste is often eliminated through burning or decomposition, leading to environmental concerns such as air pollution and carbon emissions (Serebrennikov et al., 2020). The adverse environmental and sustainability implications of agricultural waste incineration have raised awareness of the need for alternative solutions (Omar & Fatah, 2021). Several initiatives aim to transform agricultural waste into valuable resources to promote a more sustainable agricultural industry. For instance, coconut waste including husks, shells, and coir can be processed into value added products such as fibres for ropes, mats, and brushes, as well as biochar for soil enhancement (Sarkar et al., 2021; Muriuki et al., 2024). However, the underdevelopment of processing technologies and the lack of large-scale commercial production remain significant barriers to optimising resource recovery and maximising environmental benefits.

Coconut waste including husks, shells, coir, pith, and copra by products constitutes a major residue from coconut processing. These materials are often discarded through incineration or landfilling, contributing to air pollution, greenhouse gas emissions, and soil degradation (Vieira et al., 2024; Romali et al., 2023). The decomposition of coconut husks releases methane, exacerbating climate change, while improper waste disposal can lead to water contamination and pest infestations, posing risks to agriculture and public health. Despite these challenges, coconut waste possesses valuable physicochemical properties, including high lignin content, fibrous structure, and moisture absorption capacity, making it suitable for various applications (Vieira et al., 2024). Coir and husks can be processed

into bioadsorbents for wastewater treatment, effectively removing heavy metals and organic pollutants, while activated coconut shells serve as efficient filtration media due to their high surface area and adsorption capacity (Romali et al., 2023). Additionally, coconut pith and coir have been increasingly utilised in biodegradable packaging and composite materials, providing sustainable alternatives to synthetic products (James & Yadav, 2021).

The optimisation of coconut waste supports a circular economy by converting waste into valuable resources while reducing environmental impacts. For example, coconut shells can be repurposed into souvenirs and decorations, as illustrated in Figure 1. Sustainable waste management practices including the repurposing of coconut residues for industrial applications have the potential to mitigate carbon emissions, conserve energy, and generate economic opportunities for local communities (Hajam et al., 2023). By integrating ecofriendly technologies, coconut waste can contribute significantly to long term environmental sustainability and resource efficiency.

Figure 1. The conversion of coconut shell by Bagan Datuk locals.

Methodology

A preliminary study was conducted to ensure the questionnaire's acceptability, reliability, clarity, and ease of understanding for respondents. A structures survey was conducted among 30 randomly selected smallholders in Bagan Datuk. Data collection occurred between July 2024 to October 2024, ensuring recent and relevant insights. This research aimed to serve as an exploratory exercise to assess the general feasibility of the survey instrument. The primary data for this study was collected through a survey using a structured questionnaire. The Theory of Planned Behaviour (TPB) was adapted and improved to explore smallholders' perspectives on the sustainable management of coconut waste (Hendrawan & Musshoff, 2024; Widayati et al., 2023). According to TPB, intention is shaped by three independent variables: smallholders' attitudes towards sustainable management, subjective norms, and perceived behavioural control as shown in Figure 2 below.

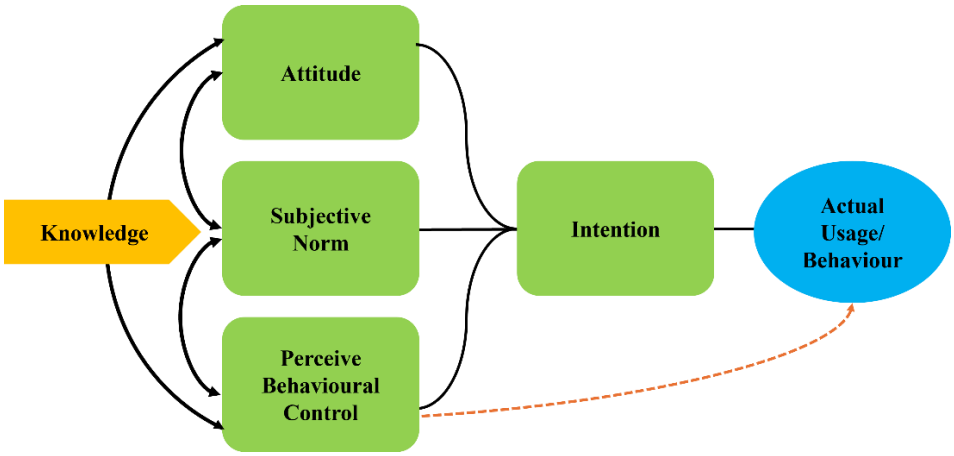

Figure 2. Theory of Planned Behaviour (Widayati et al., 2023)

A total of 30 coconut smallholders from Bagan Datuk, Perak, participated in the study. A Likert scale ranging from 1 to 5 (with 1 being Strongly Disagree and 5 being Strongly Agree) was used to assess respondents' views on statements related to sustainable coconut waste management as shown in Figure 3 below. Reliability and descriptive analysis were applied to analyze the collected data and achieve the study's objectives.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	**2**	**3**	**4**	**5**

Figure 3. The Likert scale used in the survey

This study advances understanding by integrating TPB into the analysis of agricultural waste management. Unlike previous research, which primarily focuses on large-scale plantation waste management, this study provides a micro-level perspective by examining independent smallholders' decision-making processes. Findings contribute to policy formulation and sustainable development frameworks

Reliability Analysis

Reliability is an assessment of the degree to measure consistency between multiple measurements of variables. Cronbach's alpha with the value of more than 0.60 is used as a guideline to measure the reliability of the measurement in this preliminary study (Taber, 2017). A reliable scale will produce consistent result when repeated measurements are made (Taber, 2017). Table 1 indicates that Cronbach's alpha for this study is 0.938 which is excellent and the validity was ensured through content validation by two experts in the field of technology adoption and agriculture. Feedback from these experts helped refine the phrasing and relevance of the items to align with the study objective.

Table 1. The Cronbach's Alpha Reliability

Construct	Number of Items	Cronbach's Alpha	Interpretation
Smallholders' attitudes, management and behaviour.	22	0.938	**Excellent**

RESULTS AND DISCUSSION

Demographic Profile

The demographic profile analysis of the survey respondents in Table 2 revealed that most participants were aged between 31 and 40 years, accounting for 40% of the sample, with a mean age of 40.33 years (±40 years). The distribution included 20% under 30 years, 20% aged 41–50 years, 10% between 51–60 years, and 10% aged 61–70 years which suggests that this age group may be more active and engaged in agricultural practices, potentially due to their physical capability and established positions in the industry (Brown et al., 2018). However, it also indicates that there may be challenges in reaching younger or older generations, which could impact the generalizability of findings if younger or older age groups have different perspectives on sustainable practices (Wiernik et al., 2016).

Table 2. The demographic profile of smallholders (respondents).

Demographic Profile	Frequency (n)	Percentage (%)	Mean (x̄)
Age			
<30	7	20	**40.33 (±40 years)**
31 – 40	11	40	
41 – 50	6	20	
51 – 60	3	10	
61 – 70	3	10	
Education			
No formal education	1	3.3	
Primary	4	13.3	
Secondary	20	66.7	
Diploma	3	10	
Degree or Higher	2	6.7	
Monthly Income			
<RM1,000	9	30	**RM2500**
RM1,001-RM3,000	11	36.7	
RM3,001-RM5,000	8	26.7	
>RM5,001	2	6.7	
Farm Size (acre)			
<10 acres	24	80	**9.6817 (±9.7 acres)**
11-20 acres	1	3.3	
21-30 acres	3	10	
31-40 acres	2	6.7	
Experiences			
<5 years	9	30	**11.07 (±11 years)**
6-10 years	8	26.7	
11-15 years	4	13.3	
16-20 years	6	20	
21-25 years	2	6.7	
26-30 years	1	3.3	

Table 2 also explains regarding educational attainment, a significant proportion (66.7%) of respondents had completed secondary education. This could imply that respondents are likely familiar with basic agricultural practices and potentially open to adopting sustainable methods that the smallholders perceive as beneficial (Wiernik et al.,

2016). Followed by 13.3% with primary education, 10% holding diplomas, and 6.7% with a degree or higher qualification suggests a segment of the community that may be more informed and receptive to innovative approaches, such as advanced waste management strategies (Wee & Singaravelloo, 2018). Only 3.3% reported no formal education. Monthly income levels showed that 36.7% of participants earned between RM1,001 and RM3,000; indicate that a significant portion of smallholders may face financial constraints that could affect their ability to implement sustainable practices that require initial investment (Wee & Singaravelloo, 2018).

The distribution of income levels also underscores potential economic barriers to adopting environmentally friendly technologies or practices, as those with lower earnings may prioritize short-term financial needs over long-term sustainability investments (Hajam et al., 2023; James & Yadav, 2021). While 30% had an income of less than RM1,000. The remaining respondents had monthly earnings ranging from RM3,001–RM5,000 (26.7%) to over RM5,000 (6.7%). The farm size data indicated that 80% of smallholders managed farms of less than 10 acres, with an average farm size of 9.68 acres (±9.7 acres). Smaller farm sizes were reported by 3.3% of respondents with 11–20 acres, 10% with 21–30 acres, and 6.7% with 31–40 acres. Experience levels varied, with 30% having less than 5 years of experience and a mean of 11.07 years (±11 years). This suggests that while there are many newer farmers who may be open to learning and adapting to sustainable practices, there is also a substantial group with moderate to extensive experience (Serebrennikov et al., 2020; Haleem et al., 2022). Other experience ranges included 26.7% with 6–10 years, 20% with 16–20 years, 13.3% with 11–15 years, 6.7% with 21–25 years, and 3.3% with 26–30 years of experience. This comprehensive demographic analysis offers valuable insights into the characteristics of the survey participants, which are essential for understanding their perspectives on sustainable agricultural practices. The demographic profile indicates a farming community that is relatively young and educated but faces economic challenges and limited land size.

Smallholder's Knowledge on Sustainable Management of Coconut Waste

The disposal of coconut waste through burning and dumping results in substantial environmental harm. Inappropriate waste management contributes to greenhouse gas emissions, soil degradation, and water contamination. The decomposition of coconut husks releases methane, a potent greenhouse gas, further exacerbating climate change. Additionally, improper waste disposal can lead to pest infestations, affecting both agriculture and human health. The survey results in Table 3 reveal a high level of awareness and positive attitudes among respondents towards the sustainable management of coconut waste. The responses indicate that most participants are aware of the potential uses of coconut husk as an agricultural product, with a mean score of 4.42, suggesting that over half of the respondents strongly agreed with this statement. This reflects a solid understanding of the benefits of utilizing coconut by-products (Moreno et al., 2020). Similarly, the mean score of 4.27 demonstrates that respondents believe effective waste management practices can minimize energy and financial losses, with 46% strongly agreeing. This suggests that there is confidence in the economic and environmental benefits of implementing effective coconut waste practices (Man & Shah, 2020). Respondents also displayed strong awareness regarding the use of coconut waste to create new products, such as paper bags (Noor et al., 2020), as indicated by the mean score of 4.26. This suggests that there is a substantial understanding of the innovative potential of repurposing waste (Noor et al., 2020). Additionally, the mean score of 4.13 for converting coconut waste into organic fertilizer reflects that many respondents recognize the

agricultural benefits of this practice. The data further reveals that the majority, 56%, strongly agreed that having adequate knowledge about waste processing is necessary for effective management, supported by a mean score of 4.39. This underscores the critical role that education and training play in enabling smallholders to adopt sustainable practices (Zulkipli et al., 2022).

However, a mean score of 3.72 for the statement on time constraints indicates that respondents somewhat agree that limited time to acquire knowledge hinders coconut waste processing (Azeta et al., 2021; Omar et al., 2023). While 40% agreed and 26% strongly agreed, this suggests that time constraints pose a moderate challenge to effective waste management. This finding implies that while there is a solid understanding of the benefits and processes associated with coconut waste management, addressing time limitations through targeted interventions could further improve the adoption of sustainable practices (Doe et al., 2022; Noor et al., 2020). The findings highlight a strong awareness among respondents regarding the potential and benefits of sustainable coconut waste management. This indicates that the community is receptive to adopting such practices, which is essential for promoting sustainable agricultural development (Vieira et al., 2024). The recognition of the importance of knowledge underscores the need for educational initiatives aimed at equipping smallholders with the skills and understanding required for effective waste processing (Debrah et al., 2021). However, the identified barrier of time constraints suggests that practical solutions to improve accessibility to training and resources should be explored. These could include flexible learning programs, community-based workshops, and mobile education units to overcome time limitations and facilitate the broader implementation of sustainable practices (Haleem et al., 2022; Veletsianos & Houlden, 2019). Overall, the results suggest that enhancing education and providing accessible resources can play pivotal roles in fostering sustainable management practices for coconut waste.

Table 3. Smallholders' (respondents) knowledge on sustainable management for coconut waste.

No.	Questions	1	2	3	4	5	Mean ($\bar{x}$)
1	I am aware that coconut husk can be used as agricultural products.	1.3	2.7	4	36.7	55.3	4.42
2	I believe that effective practices can minimize energy and financial losses.	0.7	3.3	10.7	39.3	46	4.27
3	I know that coconut waste can be used to create new products like paper bags.	0.7	5.3	6.7	42	45.3	4.26
4	I understand that coconut waste can be converted into organic fertilizer.	0.7	6.7	8	48.7	36	4.13
5	I have adequate knowledge about waste processing for effective coconut waste management.	0.7	2.7	9.3	31.3	56	4.39
6	I feel that limited time to acquire knowledge hinders coconut waste processing.	3.3	13.3	17.3	40	26	3.72

Connection to the Theory of Planned Behaviour (TPB)

The study findings align with the Theory of Planned Behaviour (TPB), which states that smallholders' intentions towards sustainable coconut waste management are shaped by three key factors: attitudes, subjective norms, and perceived behavioural control (Hendrawan & Musshoff, 2024; Widayati et al., 2023). The survey results show that smallholders with a positive perception of sustainable waste management practices are more likely to implement them. A high mean score of 4.39 indicates strong agreement with statements about the benefits of repurposing coconut waste. Many respondents believe that sustainable waste management reduces environmental pollution and generates economic benefits through alternative product creation like decoration items and compost (Mngomezulu et al., 2024). However, some smallholder's express concerns about additional labour and financial costs, highlighting the need for support mechanisms.

Social pressure from peers, government policies, and market demands significantly affect smallholders' waste management decisions which the respondents believe it is an effective practice that can minimize energy and financial losses (Nagarajan et al., 2022; Zhang et al., 2023). A mean score of 4.27 suggests that respondents who perceive strong community or regulatory encouragement are more likely to adopt sustainable practices. Smallholders indicate that government initiatives promoting sustainable agricultural practices have motivated some to reconsider waste disposal methods (Konefal et al., 2023; Siebrecht, 2020). Despite this, a lack of visible enforcement and incentives limits widespread adoption, demonstrating the need for stronger policy frameworks and awareness campaigns.

Limited financial resources, lack of technical knowledge, and time constraints are the main factors affecting smallholders' awareness and ability to manage coconut waste sustainably (Abidin et al., 2024). A mean score of 4.42 reflects concerns about affordability and accessibility of waste processing technologies. Respondents indicate that they would be more willing to adopt sustainable waste management practices if provided with government grants, training programmes, or technological support. Additionally, those with prior experience in waste management reported higher perceived control and confidence in their ability to process coconut waste effectively (Siebrecht, 2020). This suggests that targeted capacity-building initiatives could significantly enhance adoption rates. The findings confirm that attitudes, subjective norms, and perceived behavioural control significantly influence smallholders' decision-making processes regarding coconut waste management. Smallholders with strong positive attitudes and higher perceived control are more likely to engage in sustainable waste practices, supporting TPB's application in this agricultural context (Cheng, 2020; Sihombing et al., 2024). By addressing financial and knowledge barriers while reinforcing positive social norms, stakeholders can enhance sustainable waste management adoption among smallholders in Bagan Datuk.

CONCLUSION

This preliminary study on the sustainable management of coconut waste among smallholders in Bagan Datuk, Perak, Malaysia, highlights both the opportunities and challenges in waste valorisation. While there is strong awareness of the economic and environmental benefits of repurposing coconut waste into agricultural products, organic fertiliser,

and other value-added items, barriers such as inadequate training and time constraints hinder full adoption. To overcome these challenges, strategic interventions are necessary, including targeted educational initiatives, financial incentives, and collaborations with industry stakeholders to facilitate waste upcycling. Providing structured training programmes, offering subsidies for green technologies, and fostering partnerships between smallholders and enterprises will enhance resource efficiency, support economic growth, and contribute to long term environmental sustainability. This study underscores the need for integrated policy frameworks that empower smallholders to optimise coconut waste management, laying the foundation for future research and policy development in Malaysia and similar agricultural communities.

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AUTHOR CONTRIBUTIONS

Muhammad Zakwan Anas Abd Wahid is responsible on the conceptualization, methodology, data collection, data analysis, manuscript writing, and project administration. Muhamad Nazarwin Zainal Abidin is responsible in the development of literature review, data validation, manuscript review, and editing. Ahnaf Irsyad Mohd Mokmin improves statistical analysis, data visualization, and interpretation of findings. Muhammad Syakir Sayuti, responsible in policy recommendations, discussion refinement, and manuscript proofreading.

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DATA AVAILABILITY

The data supporting the results and analyses presented in this study are available in the form of survey data collected during the research. Due to the nature of the study, the survey data is not publicly available but can be accessed upon request from the corresponding author, subject to ethical and privacy considerations.

COMPETING INTEREST

The authors declare that there are no competing interests.

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