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Analyzing Environmental, Social, and Economic Impacts of Patchouli Oil Production to Support SDG 12

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Abstract: This study aims to assess the implementation of the triple bottom line pillars within the operations of the Forest Farmers Group (Kelompok Tani Hutan, or KTH) Lentera O3 as a reference for fulfilling social, environmental, and economic standards, which are aligned with SDG 12 (responsible consumption and production). The research adopts a qualitative method with data collected through observation and interviews. Informants are selected using purposive sampling, and the data are analyzed using explanation-building analysis. Research findings indicate that KTH Lentera O3 applies the triple bottom line pillars in patchouli cultivation and patchouli oil production through the integration of social, environmental, and economic aspects. This implementation supports the achievement of SDG 12 through economic structure development, pollution-minimizing operational policies, circular economy practices (reuse and recycle), sustainability-oriented downstream initiatives, and operational alignment with responsible consumption and production. The novelty of this study lies in the application of the triple bottom line as an analytical framework to measure social, economic, and environmental impacts in the context of a local community in Indonesia. The practical implications of this research serve as a benchmark for other entities or communities in implementing the triple bottom line to support the realization of SDG 12.

Introduction

The growing urgency to achieve sustainable development continues to challenge countries to balance human welfare, environmental stewardship, and economic growth. The Sustainable Development Goals (commonly known as the SDGs) represent a global action plan that emphasizes human, environmental, and economic sustainability (people, planet, prosperity) (United Nations, 2015). The SDGs introduced by the United Nations provide a framework that integrates human–environment relations with technological innovation, thereby encouraging a more balanced and sustainable development approach (van Zanten & van Tulder, 2021). In Indonesia, the implementation of the SDGs is formally institutionalized through Presidential Regulation No. 59 of 2017, which mandates the integration of SDG principles across governmental, private, and community-based entities.

At the local level, community-based organizations play a crucial role in operationalizing SDG principles, particularly within the agricultural and forestry sectors. One such actor in Indonesia is the Forest Farmers Group (Kelompok Tani Hutan, or KTH), a community of farmers engaged in forestry-related activities both inside and outside designated forest areas, including the production of non-timber forest products and environmental services (Kementerian Kehutanan Republik Indonesia, 2014). Through their daily operational practices, KTHs directly influence local socio-economic conditions and environmental outcomes. Although improvements in capacity and literacy may enhance productivity and resource allocation efficiency (Sidhoum & Vrachioli, 2025), sustainability-oriented management practices remain uneven and insufficiently standardized across KTH operations.

One region with active KTH engagement is Madiun City, where KTH “Lentera O3”, located in Oro-Oro Ombo Subdistrict, Kartoharjo District, focuses on patchouli cultivation. Patchouli (Pogostemon cablin), an aromatic plant from the Lamiaceae family, is widely cultivated in tropical and subtropical regions bioactive secondary metabolites (Xie, et al., 2017) and holds significant economic value due to its (Kumar, Sharma, Chanotiya, & Lal, 2024). Patchouli produced by KTH Lentera O3 serves as a raw material for perfumes, soaps, and other derivative products. Green and sustainable resources are one of many sector to empower local communities (Sirait, Susanto, Zuhrohtun, & Mulyanto, 2025). However, the processing activities (particularly distillation) exhibit inefficiencies in resource consumption and lack systematic environmental impact assessment, indicating misalignment with sustainable production principles.

To address these challenges, the triple bottom line (TBL) framework offers a comprehensive analytical approach that integrates economic, social, and environmental dimensions. Prior studies emphasize that organizations can operationalize TBL through circular economy strategies, pollution reduction, and socially inclusive practices (Mouazen, Hernandez-Lara, Chahine, & Halawi, 2025). The TBL framework can also be aligned with the SDGs to generate measurable action, that is outcome linkages (Narassima, et al., 2025). Given that SDG 12 focuses explicitly on responsible consumption and production, measured through waste reduction, reuse, recycling, and resource efficiency, TBL provides a relevant framework for evaluating patchouli processing activities and their environmental and socio-economic impacts (Zhou, et al., 2025). Integrating TBL into business operations results in alignment between business goals (profit) and stakeholder interests, including those of people (social) and the environment (ecological). Thus, given that SDG 12 focuses on responsible consumption and production (measured through waste minimization, reuse, recycling, and resource efficiency), TBL becomes a strategic framework for evaluating patchouli distillation processes and their outputs.

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While existing studies demonstrate that TBL can harmonize economic performance with social welfare and environmental management (Javed, Ali, Asrar-ul-Haq, Ali, & Kirmani, 2020) and that SDG 12 supports transitions toward circular economy models (Cifuentes-Faura, 2025) empirical evidence remains limited at the micro-community level in Indonesia. Although the literature on TBL and SDG 12 has developed, empirical studies examining the application of TBL within micro-scale forest farmer groups processing non-timber forest products, such as patchouli, in urban or peri-urban Indonesian contexts remain very limited.

Based on this gap, this study aims to assess the implementation of the triple bottom line pillars within KTH Lentera O3 in relation to SDG 12 (responsible consumption and production). The study also examines how circular economy practices embedded in patchouli cultivation and distillation support responsible production outcomes. The novelty of this research lies in providing empirical evidence of TBL application at the community level in Indonesia and explicitly linking it to SDG 12 achievement.

The findings of this study are expected to offer alternative best practices for other communities involved in patchouli processing, particularly regarding sustainable economic, environmental, and social impacts. To systematically address these objectives and strengthen analytical coherence, this study formulates the following research questions:

1. How is the triple bottom line implemented in the operational activities of the Forest Farmers Group “Lentera O3”?
2. How does the application of the triple bottom line support the achievement of SDG 12?

Research Method

This study employs a qualitative approach, selected to obtain an in-depth understanding of the activities, processes, and operational dynamics of patchouli cultivation at KTH Lentera O3. Qualitative research is descriptive in nature, relies heavily on analytical interpretation, and highlights participants’ perspectives (A’yun, Habsy, & Nursalim, 2025). Qualitative methodology provides data analysis procedures that are inductive (derived from participants), constructed (contextual), and complex (defining, replicating, or precisely controlling phenomena) (Burney, Arnold-Saritepe, & McCann, 2023).

The research population consists of members of KTH Lentera O3 involved in processing patchouli into essential oils and derivative products. Samples were selected using purposive sampling, where informants are chosen based on their roles and competencies in the operational process—from patchouli cultivation to downstream patchouli oil processing.

This research utilizes three theoretical measurements: (1) organizational capacity to implement the triple bottom line; (2) SDG 12 (responsible consumption and production), emphasizing cleanliness and greening; and (3) integration of economic and social value in sustainable strategies. These theories align with previous studies, outlined as follows:

1. An organization’s ability to balance consumer and environmental interests through pollution reduction, reuse, recycling, and repackaging has been evaluated as an instrument for enhancing triple bottom line implementation (Saglam, 2023).
2. Through responsible production and consumption, organizations focus on promoting a circular economy emphasizing cleanliness and greening (Balsalobre-Lorente & Shah, 2024).
3. Business management integrates social and economic pillars into sustainable strategies to achieve the required balance (Pasamar, Bornay-Barrachina, & Morales-Sanchez, 2023).

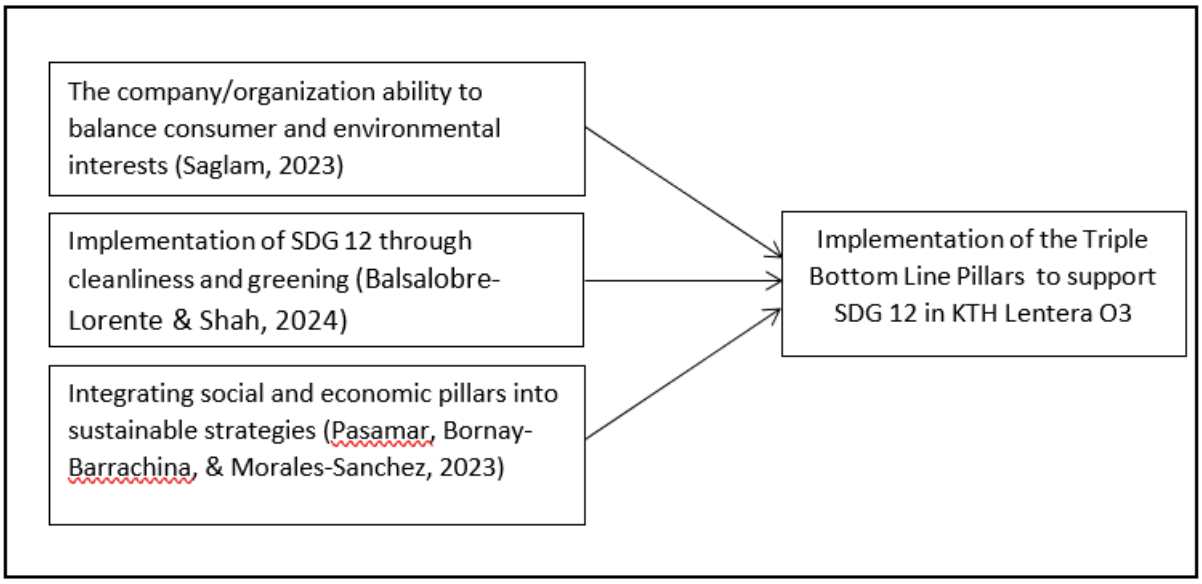

Figure 1. Research Design

The data collection techniques used in this study were interviews and observations. Interviews are a fact-gathering approach in which the interviewer poses questions to respondents, typically in a face-to-face setting (Mazhar, Anjum, Anwar, & Khan, 2021). The interviews were conducted with the Deputy Chairperson and Secretary of the Forest Farmers Group Lentera O3, both of whom possess in-depth understanding of essential oil production activities and the handling of production residues.

Furthermore, observation is an approach used to monitor participants in their natural environment from a distance, thereby providing additional information for the study (Ghanad, 2023). Observations were carried out during essential oil production activities and the treatment of production waste, which is further processed into products with economic value.

The data analysis technique employed in this study was explanation building analysis. Explanation building analysis is a data analysis method used to explain a phenomenon as a basis for establishing a sequence of cause-and-effect relationships that lead to certain outcomes (Yin, 2018). This technique is relevant for answering “how” and “why” research questions, enabling the analysis to guide the researcher toward conclusions that align with the study’s objectives.

Result and Discussion

Result

Environment Pillar

The distillation of patchouli leaves and stems generates residues in the form of hydrosol, boiled water, and solid waste, all of which have the potential to reduce environmental quality if left unmanaged. To address this issue, the Forest Farmers Group (KTH) Lentera O3 implements residue management practices that convert these outputs into products with added economic value. The management of patchouli oil distillation residues is presented in Table 1.

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Table 1.
Management of Patchouli Oil Distillation Residues from an Environmental Perspective

Type of Residue	Residue Description	Residue Management
Hydrosol	An aromatic liquid produced during the patchouli distillation process, containing minimal oil content (predominantly water).	Hydrosol is used as a mixture in producing aromatics, diffusers, and soap.
Boiled Water	A liquid residue from patchouli distillation with almost no oil content.	Boiled water is used as a raw material for pesticide and fertilizer products.
Solid Residue	Patchouli stems and leaves that have undergone the distillation process, resulting in dried leaves and stems.	Solid residues are used as raw materials for fertilizer, incense, and briquette production.

Sources: Adapted from Interviews with Kodrat and Field Observations

The conversion of hydrosol, boiled water, and solid residues into secondary products demonstrates the group's effort to reduce waste accumulation and environmental pollution. These practices indicate that residues are treated not as waste, but as reusable resources, reflecting an early-stage circular economy approach. Without such management, residues, particularly boiled water and fine solid residues, could generate odor pollution and reduce environmental hygiene in surrounding residential areas.

The consistency of residue management practices since the beginning of distillation activities suggests that environmental considerations are embedded within operational routines rather than applied as ad hoc mitigation measures. This indicates a proactive approach to environmental responsibility at the community level.

Social Pillar

Residue management also serves as a concrete effort to maintain the quality of life of communities living around the distillation site. Improper handling of distillation residues could negatively affect nearby residents through odor, water contamination, or environmental discomfort. The social impacts of residue management presented in Table 2.

Table 2.
Social Impacts of Patchouli Oil Distillation Residue Management

Type of Residue	Management Method	Social Impact of Residue Management
Hydrosol	Placing hydrosol into sealed bottles	Members of the farmers' group and surrounding residents are protected from water pollution, including potential liquid contamination.
Boiled Water	Storing boiled-water residue in large containers (e.g., buckets) placed far from areas of activity	Members of the farmers' group and surrounding residents are protected from air pollution caused by the strong, distinctive odor of the boiled water.
Solid Residue	Placing distilled stems and leaves into large containers positioned away from wind exposure	Residential areas surrounding the distillation site remain free from scattered leaves and stems, thus maintaining environmental cleanliness.

By sealing hydrosol, isolating boiled water, and storing solid residues away from wind exposure, KTH Lentera O3 minimizes social disturbances and protects community well-being. These practices demonstrate how environmental management directly contributes to social sustainability, supporting the social pillar of the triple bottom line.

In addition to residue management, the use of low-noise distillation equipment further reduces negative externalities, particularly noise pollution. Moreover, the involvement of local housewives in patchouli cultivation activities reflects inclusive participation and skill development, which are key indicators of social sustainability. This approach not only enhances local capacity but also strengthens community ownership of sustainable practices.

Economic Pillar

From an economic perspective, KTH Lentera O3 has progressed to the cultivation and initial downstream processing phase of patchouli oil production. The economic activity milestones of the group are illustrated in Figure 2.

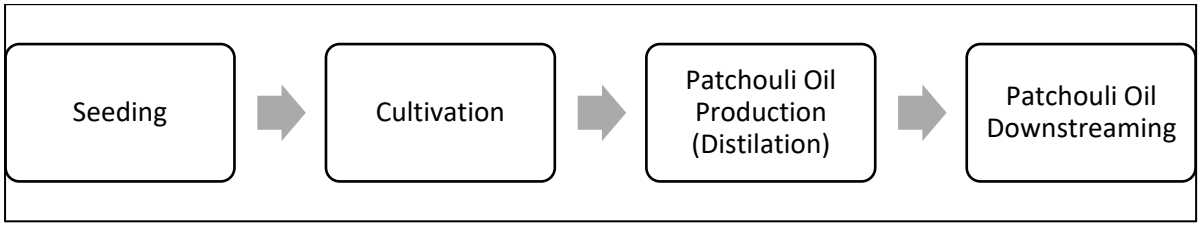

Figure 2. Economic Activity Milestones of the Forest Farmers Group Lentera O3

Downstream processing experiments include the production of bath soap, perfume, and aromatherapy products. Although these products have not yet entered mass markets, they function as pilot initiatives to test product safety, feasibility, and market acceptance. Such experimentation reflects a risk-managed strategy that prioritizes learning and product validation before scaling, rather than immediate profit maximization.

Economic calculations indicate that patchouli oil meeting Indonesian National Standards (SNI) yields a contribution margin of Rp150,000 – Rp300,000 per kilogram. Downstream products generate even higher margins, particularly aromatherapy products, with margins reaching 150%–177% per unit. These findings suggest that value addition through downstream processing significantly enhances economic potential compared to selling raw patchouli oil alone.

However, production capacity remains limited due to small-scale distillation equipment. This limitation constrains revenue generation but simultaneously reduces environmental pressure, unintentionally supporting responsible production principles. Scaling production would require expanded cultivation areas and coordinated planting cycles, indicating that economic sustainability is closely linked to land-use planning and resource availability. For downstream product development experiments, the group created projected calculations using the assumption of household-scale production because mass production has not yet been conducted. The downstream experiments included producing bath soap and aromatherapy products. The compositions of the main raw materials for each production batch and variable cost estimates are presented as follows.

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Table 3.
Composition of Raw Materials and Output of Patchouli Oil Downstream Products

Product Type	Main Raw Materials	Composition	Production Output
Bath Soap	Coconut Oil	97%	20–22 bars of bath soap per batch @50 grams
	Palm Oil	—	
	Patchouli Oil	2%–3%	
Aromatherapy	Citronella Oil	70%–85%	1 bottle of aromatherapy @10 ml
	Patchouli Oil	15%–30%	
	Packaging	1 set	

Source: Adapted from Interviews with Kodrat & Joko

Table 4.
Estimated Production Costs of Patchouli Oil Downstream Products

Product Type	Main Raw Materials	Estimated Production Cost (Rp)	Selling Price (Rp)
Bath Soap	Coconut Oil	3,300 – 3,500	5,000
	Palm Oil		
	Patchouli Oil		
Aromatherapy	Citronella Oil	7,200 – 8,000	20,000
	Patchouli Oil		
	Packaging		

Source: Adapted from Interviews with Kodrat & Joko

Based on the cost calculations from the downstream experiments, bath soap generates a margin of 42.8% – 51.5% per 50-gram packaged soap, while aromatherapy products generate a margin of 150% – 177% per 10 ml bottle. These cost estimations assume that the patchouli oil used is produced internally by the KTH Lentera O3. If purchased from other farmer groups or companies, the cost of patchouli oil would increase.

Another important consideration is the limited production capacity of patchouli oil from the current distillation process. The patchouli distillation machine currently has a production capacity of 30–50 grams per batch, with each batch requiring 8 hours. Consequently, the group's daily production capacity ranges between 60 grams and 100 grams of patchouli oil. Therefore, the highest economic outcome is derived from producing 40 – 60 bottles of 10 ml aromatherapy, which yields a contribution margin of Rp12,000 – Rp12,800 per bottle.

These cost estimates are based on small-scale production, and costs can be reduced once the supply of patchouli reaches a higher volume. According to Kodrat, one of the key informants, scaling cultivation to a business-level operation requires 150 kilograms of patchouli raw material per month. Achieving this amount requires five hectares (Ha) of cultivation area with five staggered planting cycles to ensure continuous supply. Each hectare is projected to accommodate approximately 15,000 patchouli seedlings, which can produce around 150 kilograms of patchouli oil. If these criteria are met, the KTH Lentera O3 will be able to operate a sustainable patchouli-based business.

Discussion

Application of the Triple Bottom Line at KTH Lentera O3

The findings indicate that KTH Lentera O3's operational practices align with the triple bottom line (TBL) framework, which emphasizes the integration of economic viability, social responsibility, and environmental protection (Abraham, 2024). This alignment is evident in residue management, inclusive community participation, and downstream product

development. From an ethical perspective, KTH Lentera O3 manages the residues generated from production in a way that minimizes negative environmental impacts and prevents environmental damage. By reducing these negative impacts on the environment, the social impact on the surrounding community is also addressed, as no residue is dispersed into residential areas. From a business sustainability perspective, KTH Lentera O3 conducts downstream processing experiments for patchouli oil and designs several derivative product options made from distillation residues. In addition to patchouli oil downstreaming and prototype development of derivative products, KTH Lentera O3 also empowers several housewives living in nearby areas through activities related to patchouli cultivation—reflecting the organization's accountability in supporting sustainable development within its operational area.

From an environmental standpoint, residue containment and reuse demonstrate pollution prevention and resource efficiency that show measurable production outputs and controlled waste streams are key indicators of environmentally responsible production (Khakpour, Ebrahimi, & Saghiri, 2023) has been implemented in KTH Lentera O3's activities. This is evidenced by the proper containment of patchouli oil distillation residues in designated storage containers. This condition indicates two things: 1) production outputs are measurable, and 2) the residues/waste generated can be properly managed, thereby maintaining environmental quality.

Socially, KTH Lentera O3 reduces negative externalities such as noise and odor pollution while empowering local housewives through cultivation activities. These practices are consistent with previous research that state who emphasize that social sustainability in small-scale enterprises is often reflected through reduced community disturbance and inclusive engagement rather than formal social programs (Pasamar, Bornay-Barrachina, & Morales-Sanchez, 2023). The integration of the social and economic pillars is illustrated as follows.

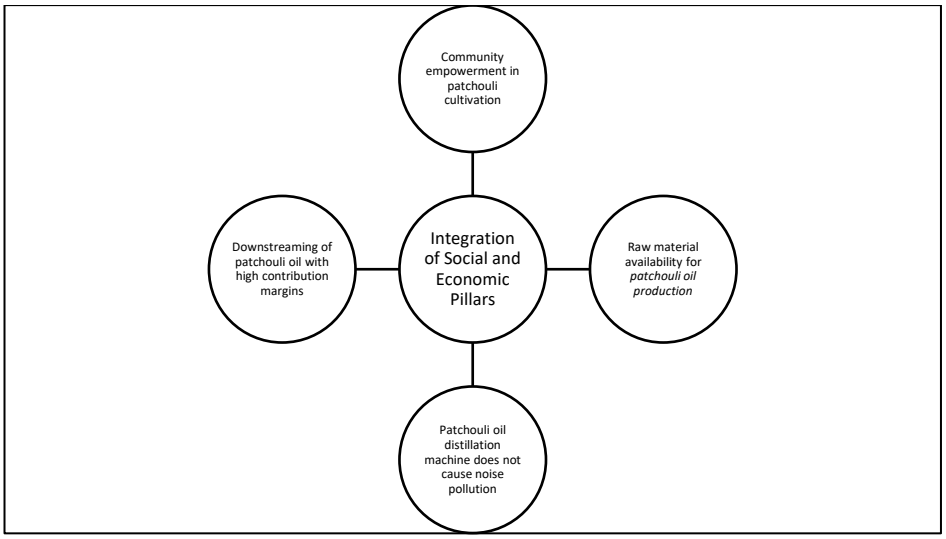

Figure 3. Integration of Social and Economic Pillars at KTH Lentera O3

Economically, downstream processing experiments illustrate the group's effort to diversify income sources and enhance value creation. Although commercialization remains limited, these initiatives function as preparatory mechanisms for sustainable scaling rather than short-term profit extraction. Based on pollution reduction, reuse, and recycling indicators (Table 5), KTH Lentera O3 demonstrates effective application of TBL principles

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within its patchouli cultivation and processing activities that supporting argument that operational tools such as reuse and recycling strengthen TBL implementation (Saglam, 2023).

Tabel 5.
Indicators for Evaluating Triple Bottom Line Implementation at KTH Lentera O3

Evaluation Indicator	Implementation
Pollution Reduction	Use of distillation equipment that does not generate noise pollution storage of solid residues in areas where they cannot be dispersed by the wind
Reuse	Decomposition of solid residues into compost that naturally breaks down within designated containers without drastically altering the residue form
Recycling	Use of hydrosol as an ingredient in soap production Use of distilled water as a solvent for plant-based pesticide products such as citronella

Based on the analysis of 1) the integration of social and economic pillars, and 2) the evaluation indicators of triple bottom line implementation, KTH Lentera O3 has effectively applied the pillars of the triple bottom line within its patchouli cultivation and patchouli oil production operations.

Application of the Triple Bottom Line in Supporting SDG 12

A comprehensive and accurate assessment of SDG progress helps identify gaps within economic structures, social well-being, and environmental protection, while also providing data to support future development (Chen, Shuai, Chen , & Zhao, 2025). Based on this understanding, the implementation of the triple bottom line at KTH Lentera O3 has not been fully integrated into SDG progress assessment, particularly regarding aspects of social well-being. However, in terms of economic structures and environmental protection, KTH Lentera O3 has been able to demonstrate clear achievements.

1. Economic structure has been developed through downstream processing experiments of patchouli oil (such as soap, perfume, and aromatherapy products) and the formulation of derivative products made from patchouli distillation residues (including pesticides, fertilizers, incense, and others);
2. Environmental protection has been implemented through the use of low-noise distillation machinery, storage of patchouli oil residues that minimizes air pollution for nearby residents, and mitigation of environmental contamination caused by spilled distillation residues.

SDG 12 (responsible production and consumption) encourages organizations to focus on promoting a circular economy emphasizing cleanliness and environmental greening (Balsalobre-Lorente & Shah, 2024). Circular economy promotion centers on applying the principles of reduce, reuse, and recycle. The previous section has shown applications of reuse (solid residues converted into compost) and recycle (hydrosol used as a soap ingredient, and distilled water used as a solvent for plant-based pesticides). As for the application of reduce, it is demonstrated through: 1) the minimal amount of patchouli oil distillation residue generated, and 2) the production of only one batch per day.

The reduce principle, however, is applied implicitly rather than as a formal policy. Limited production volume and controlled batch frequency reflect responsible resource consumption driven by capacity constraints rather than intentional reduction strategies. This

pattern is common among early-stage community enterprises, where sustainability outcomes often precede formal sustainability planning.

Furthermore, downstream product development and diversification of residue-based products indicate early-stage preparation for sustainable financial access (Rahman & Hossain, 2024). First, sustainability initiatives are reflected in the downstream product experiments and diversification of derivative products made from patchouli oil distillation residues. This demonstrates that KTH Lentera O3 is developing initiatives to prepare for sustainable financial access. Second, alignment of operations with SDG 12 is shown through consumption of patchouli plants that does not exceed the capacity of the distillation machine and the matching of patchouli oil residue output with the capacity of available containers. This operational planning reflects the alignment of KTH Lentera O3's activities with the values of SDG 12.

Using the perspectives of Chen, Shuai, Chen, & Zhao (2025), Balsalobre-Lorente & Shah (2024), and Rahman & Hossain (2024), the implementation of the triple bottom line pillars in supporting SDG 12 at KTH Lentera O3 is achieved through patchouli cultivation and oil distillation via: 1) economic structure development, 2) pollution-minimizing operational policies (reduce noise and air pollution), 3) circular economy practices (reuse and recycle), 4) sustainability-oriented downstream initiatives, and 5) operational alignment with responsible consumption and production, reflected in the consumption of patchouli plants that does not exceed distillation capacity and the matching of residue output with available container capacity.

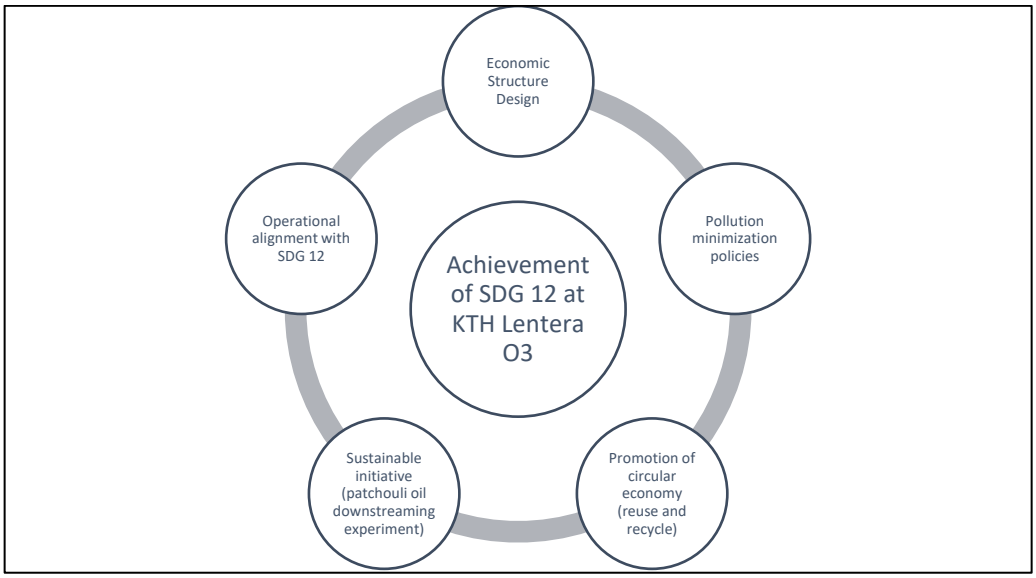

Figure 3. Implementation of Triple Bottom Line Pillars Supporting SDG 12

Conclusion

The conclusions of this study encompass two aspects: the application of the triple bottom line pillars in the patchouli oil production activities at KTH Lentera O3, and the application of these pillars in supporting the achievement of SDG 12 (responsible consumption and production). The conclusions of this study are as follows:

1. The triple bottom line pillars have been applied in the operations of patchouli cultivation and patchouli oil production through:
   a. integration of social and economic pillars, such as community empowerment in cultivation and production activities, provision of patchouli as the main raw

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material, the use of low-noise distillation machines, and downstream processing of patchouli oil with high contribution margins; and
   b. evaluation indicators of triple bottom line implementation, including reduction of noise and air pollution, reuse of distillation residues, and recycling of distillation residues into products with high economic value.
2. The application of the Triple Bottom Line pillars has supported the achievement of SDG 12, including:
   a. the design of an economic structure through cultivation and distillation activities;
   b. policies to minimize pollution through the selection of distillation machines and the determination of residue storage points;
   c. the promotion of a circular economy through reuse and recycle practices;
   d. sustainable initiatives through downstream processing experiments and diversification of products derived from distillation residues; and
   e. operational alignment with SDG 12 (responsible consumption and production) by ensuring that patchouli consumption does not exceed the capacity of the distillation machine and matching the volume of patchouli oil residues with the capacity of available containers.

The limitations of this study include: 1) the absence of community members around KTH Lentera O3 as respondents, resulting in the assessment of the implementation of social and environmental pillars being based solely on perspectives of individuals who understand the operational activities of KTH (from patchouli cultivation to downstream processing), and 2) the lack of cost calculations as a comparative tool against those conducted by KTH Lentera O3, which may lead to potential overcosting or undercosting in determining product profit margins.

Based on these limitations, the researcher recommends: 1) that future studies use convenience sampling to broaden the types of data and provide more flexible selection of respondents for assessing environmental and social pillars, and 2) the use of direct tracing or driver tracing approaches to produce more accurate cost calculations that can serve as the basis for determining selling prices.

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