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ANALYSIS AND DESIGN OF A SUSTAINABLE SMART PATCHOULI AGROINDUSTRY DEVELOPMENT SYSTEM

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ABSTRACT. Indonesia accounts for more than 95% of global nilam oil (patchouli essential oil) production; however, the country's nilam agroindustry still faces challenges such as low productivity, dependence on conventional distillation technologies, and weak coordination among value-chain actors. These constraints limit the value added and economic benefits that could otherwise accrue to farmers and local enterprises. This paper examines the patchouli agroindustry in Sukabumi Regency and proposes a framework for developing a sustainable and intelligent agro-industrial system. The study employs value chain analysis to map material and information flows, SWOT analysis to assess the industry's strategic position, and the Business Model Canvas (BMC) to design a cooperative-oriented business model. Data were collected through surveys, interviews, focus group discussions (FGDs), and field observations involving farmers, cooperatives, distillers, and traders. The results indicate that village cooperatives can play a strategic role as aggregators by facilitating quality improvement, strengthening farmers' bargaining power, and reducing their dependence on intermediaries. The SWOT analysis positions the industry in Quadrant III, corresponding to a Weakness–Opportunity (WO) strategy, indicating the need to modernize distillation processes, strengthen cooperative management, and establish and implement consistent quality standards. The proposed BMC supports the development of a consistent and traceable supply of "blending-ready" patchouli oil through an integrated feedstock structure while fostering collaboration among local small and medium-sized enterprises (SMEs). This integrated material-flow structure also provides a foundation for continuous digital monitoring, traceability, and data-driven management, thereby enhancing the overall sustainability and resilience of the patchouli agroindustry.

INTRODUCTION

Indonesia is the world's largest supplier of patchouli oil, contributing approximately 95% of the global supply and accounting for approximately 85% of the country's essential oil exports, with annual volumes of 1,200–1,500 metric tons exported to destinations, including the United States, France, and the United Kingdom (Ministry of Agriculture, 2020; Pandey *et al*., 2021). Patchouli *(Pogostemon cablin)* is not only a critical fixative in the perfume industry but also has significant applications in cosmetics, aromatherapy, and medicine (Sitanggang *et al*., 2021). Despite this dominant market position, Indonesia's patchouli agroindustry continues to face structural challenges that constrain its value-added potential.

Among these challenges are inconsistent post-harvest practices and the widespread use of traditional distillation methods that produce suboptimal quality (Salsabila *et al*., 2023). In addition, information flows remain fragmented across the supply chain (from farmers and cooperatives to distillers and exporters), limiting data-driven decision-making, weakening farmers' bargaining positions, and generating supply and price unpredictability. These conditions reflect a systemic gap between Indonesia's comparative advantage as the world's dominant producer and its capacity to capture equitable value across the supply chain.

Digital transformation offers a concrete pathway to address these weaknesses. Internet of Things (IoT) technologies can monitor cultivation and distillation conditions in real time, whereas DSS can support cooperative and farmer decision-making to improve efficiency, quality consistency, and supply chain coordination. However, adoption remains critically limited among smallholder farmers and village cooperatives (Fadilla *et al*., 2025), a gap that is particularly urgent given the growing global demand for traceable, sustainably sourced essential oils and the documented inequitable benefit distribution among patchouli supply chain actors (Keumalasari *et al*., 2025; Pramestari *et al*., 2024). This urgency underscores the need for a comprehensive integrated analysis as the foundation for designing a sustainable smart patchouli agroindustry system.

This study employs three complementary analytical methods: (1) value chain analysis to map material and information flows and identify bottlenecks; (2) SWOT analysis to evaluate the industry's strategic position; and (3) the business model canvas (BMC) to design a cooperative-centered business model. Each method is supported by a substantial body of literature in the agroindustrial context. Value chain analysis has been applied in patchouli studies using causal loop diagrams to identify supply chain bottlenecks (Rahmayanti *et al*., 2023) and the SCOR 12.0 model to map upstream and downstream processes (Maizi *et al*., 2021). SWOT analysis has been applied to patchouli agribusiness strategy (Salsabila *et al*., 2023) and validated through quantitative enhancements, including IFE/EFE matrices in agroindustrial commodity studies (Chatra and Rosi, 2025). The BMC has been empirically applied to cooperative and agroindustrial development in rice husk silica (Casnan *et al*., 2022), kenaf fiber (Nurhasanah *et al*., 2024), and integrated sustainability frameworks (Saragi *et al*., 2024). While each method is well established, no prior study has applied all three methods in an integrated sequential framework within the patchouli agroindustry context.

Prior studies on the patchouli agroindustry have approached the problem from a single-method or partial perspective, which is limited. Keumalasari *et al*. (2025) applied combined HOR and SCOR models to identify and prioritize supply chain risks; however, they did not address the business model redesign. Pramestari *et al*. (2024) conducted a systematic review emphasizing multi-criteria decision-making for supply chain performance improvement; however, they did not integrate strategic analysis or business model innovation into their study. Abdullah *et al*. (2023) explored the warehouse receipt system as a price stabilization mechanism, and Juanda *et al*. (2021) developed a nonlinear equity model to measure benefit distribution across supply chain levels. None of these studies combined operational diagnosis, strategic evaluation, and business model redesign within a single integrated analytical sequence. This study directly addresses this gap.

The novelty of this study is three-fold. Methodologically, it is the first study to integrate value chain analysis, SWOT analysis, and BMC in a sequential framework, using supply chain mapping to identify operational bottlenecks, SWOT to derive strategic priorities, and BMC to translate those priorities into a redesigned cooperative business model, in the patchouli or essential oil agroindustry context (Keumalasari *et al*., 2025; Pramestari *et al*., 2024). Contextually, this integration is applied specifically to the Indonesian patchouli agroindustry, where such an empirically validated multi-method framework remains scarce. Practically, the proposed system incorporates digital tools (IoT, DSS, blockchain-based traceability, and a B2B marketplace module) into a concrete smart agroindustry framework, responding to the call for digitalization and green technology integration (Bachmann *et al*., 2025). This digitally enabled, cooperative-centered framework represents a concrete contribution to the emerging research agenda on smart and sustainable agro-industrial development in Southeast Asia (Agus *et al*., 2025).

RESEARCH AND METHODS

Research Methods

This study addresses the core problems faced by the patchouli agroindustry in Sukabumi Regency, namely low productivity, inconsistent product quality, dependence on intermediaries, and weak value chain coordination, which collectively limit the value-added potential of farmers and local enterprises. The expected outcome of this research is a cooperative-based Business Model Canvas (BMC) grounded in value chain mapping and SWOT analysis, serving as a strategic framework for developing a sustainable and smart patchouli agroindustry system.

This study used descriptive qualitative methods to analyze the recent situation of the patchouli agroindustry and identify digital transformational development opportunities (Angi et al., 2013). The study was carried out in Sukabumi Regency, West Java, which was purposively chosen as it provided favorable agroclimatic conditions and high involvement of local institutions in the patchouli supply chain, including farmer groups and cooperatives. The study collected primary data through direct observations, in-depth interviews, and Focus Group Discussions (FGD) with farmers, village cooperatives, distillers, traders, and relevant stakeholders. Our secondary data came from scientific journals, policy documents, and technical reports relevant to patchouli agribusiness and agroindustrial business models.

As illustrated in Figure 1, this study followed a sequential methodology comprising problem identification, literature review, field data collection, three-pronged data analysis (value chain analysis, SWOT, and BMC), and FGD-based validation with stakeholders. The analytical outputs were then synthesized to produce a comprehensive situational picture of the patchouli agroindustry and a strategic framework for its digital transformation and sustainable development.

Value chain analysis has been applied in patchouli oil studies through diverse approaches: Rahmayanti *et al*. (2023) used Causal Loop Diagrams to map supply chain bottlenecks and recommend intermediary reduction, Maizi *et al*. (2020) applied the SCOR 12.0 model to formally structure upstream and downstream processes, and Keumalasari *et al*. (2025) extended this by integrating the House of Risk model to identify and prioritize supply chain risks.

The present study employs value chain analysis as a descriptive mapping tool focused on actor roles, material and information flows, and value-added identification, explicitly linking the mapping outputs to the subsequent strategic analysis and business model redesign.

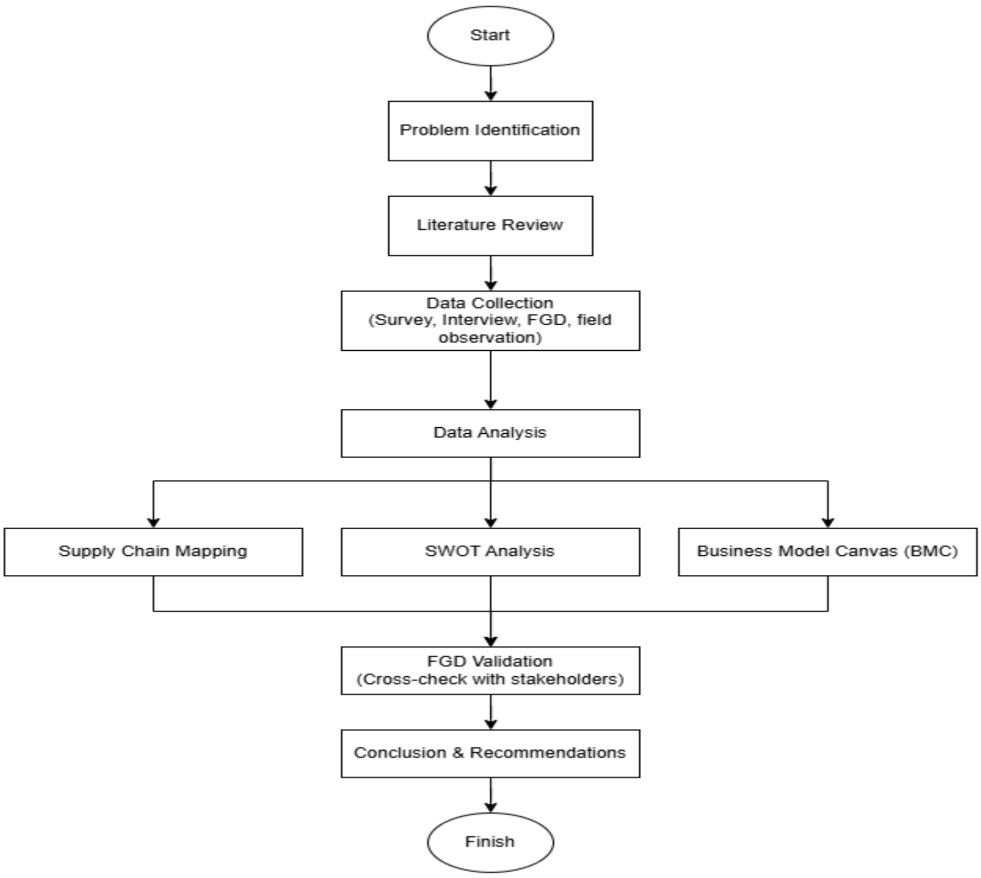

Figure 1. Research flowchart of the integrated analysis and design methodology for the sustainable smart patchouli agroindustry development system

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For SWOT analysis, Dzulkarnain *et al*. (2020) combined SWOT with AHP for patchouli partnership strategy in Konawe Regency, and Salsabila *et al*. (2023) applied it to patchouli agribusiness development, while quantitative enhancements such as IFE/EFE matrices (Chatra and Rosi, 2025) and SWOT-AHP integration (Etongo *et al*., 2023) have been demonstrated to reduce subjectivity in related agroindustrial contexts; the present study adopts a weighted-rating IFAS/EFAS approach that balances quantitative grounding with multi-stakeholder accessibility. The Business Model Canvas has been applied across Indonesian agroindustry sectors including coconut fiber (Bahayyil *et al*., 2025), rice husk silica (Casnan *et al*., 2022), kenaf fiber (Nurhasanah *et al*., 2024), and essential oil-based products (Hidayat *et al*., 2021); in contrast, the present study positions BMC as the synthesis output of both value chain mapping and SWOT analysis, ensuring the resulting cooperative business model is grounded in empirical field data and strategic priorities.

Data Analysis

Three analytical models were employed for descriptive data analysis. Value chain analysis was applied to trace the flows of products, information, and value-added from upstream to downstream actors (including farmers, cooperatives, distillers, traders, and exporters) with emphasis on identifying bottlenecks, processing inefficiencies, and coordination gaps that digitization could address (Juanda *et al*., 2021). This method was selected for its ability to visually map material and information flows across all chain actors, although it is limited in quantifying value distribution as it relies primarily on qualitative field observations.

SWOT analysis was conducted to identify the strengths, weaknesses, opportunities, and threats of the patchouli agroindustry as a basis for formulating development strategies for the industry. Internal and external factors were derived from fieldwork, interviews, and literature on patchouli commodity development and market dynamics (Lufika *et al*., 2023). While SWOT is valued for its ability to synthesize diverse data sources into actionable strategies, the method is inherently subjective; the weighting and rating of factors depend on researcher and respondent judgment.

The Business Model Canvas (BMC) was applied to map the current and proposed business model of the patchouli agroindustry across nine components: customer segments, value propositions, channels, customer relationships, revenue streams, key activities, key resources, key partners, and cost structures (Novitasari *et al*., 2021). The BMC was selected for its ability to present a comprehensive business model in a single integrated framework, facilitating communication and alignment across diverse stakeholders. Its application revealed opportunities for cooperatives to function as value-added centers through digital technology integration, consistent with agro-industrial business model studies in related sectors (Nurhasanah *et al*., 2024). However, its limitation is that it does not capture dynamic market conditions or detailed financial projections.

The FGD served as a validation mechanism to cross-check the value chain, SWOT, and BMC findings against real conditions on the ground, ensuring that the analytical conclusions reflected stakeholder realities. Participants, including farmers, cooperatives, distillers, and other agroindustry actors, collectively identified value-added opportunities and aligned on a pragmatic development trajectory for a sustainable patchouli agroindustry.

Fifteen respondents were engaged across seven categories of supply chain actors, from upstream producers to end-market buyers, ensuring full coverage of the patchouli oil value chain from cultivation to export. The number of respondents per category was determined based on data saturation, where collection continued until no new themes emerged; empirical reviews indicate saturation in qualitative studies with narrowly defined populations is typically reached at 9–17 interviews or 4–8 focus group discussions (Hennink and Kaiser, 2022; Squire *et al*., 2024).

RESULTS AND DISCUSSIONS

Value Chain Analysis of the Patchouli Agroindustry
Analysis of Patchouli Oil Processing

The development of the patchouli agroindustry in Sukabumi Regency centers on empowering village cooperatives to aggregate raw materials from local farmer groups and process them into industrial-grade patchouli oil. Processing begins with harvesting leaves at 6–7 months of plant age, when the essential oil content is at its peak. Older plants tend to shed leaves and produce stiffer stems that reduce oil quality (Herdiansyah *et al*., 2023).

Table 1. Profile of respondents engaged in the sustainable smart patchouli agroindustry development system

Respondent category	Number of respondents	Role in supply chain	Method of data collection	Key characteristics
Farmers	4	Raw material supplier	Interview & FGD	Years of experience, land size, location
Farmer Groups	2	Collective raw material management	Interview & FGD	Number of members, active/inactive status
Village Cooperative Initiator	1	Aggregator & distillation coordinator	Interview & FGD	Stage of formation, distillation capacity
Distillers	2	Oil processing	Interview & FGD	Scale of operation, technology used
Traders / Collectors	2	Distribution intermediary	Interview & FGD	Coverage area, years in trade
Exporters	1	End-market linkage	Interview & FGD	Export destination, volume
Government / DAI Representatives	3	Policy & institutional support	Interview & FGD	Agency name, position
Total	**15**			

Freshly harvested leaves are then naturally dried by hanging or rack-drying to reduce moisture to approximately 15% and achieve a 75–80% weight reduction. This method is preferred over direct sun exposure as it minimizes oil evaporation and preserves active components (Chotimah *et al*., 2023).

As illustrated in Figure 2, partial fermentation following drying initiates patchouli alcohol development, which significantly influences final oil quality. Shredding after drying increases the surface area and improves the distillation efficiency. Steam distillation (the primary processing stage) uses stills of 100–500 kg capacity, operating at 100–120°C and 0–1 bar for 6–8 h; these conditions are selected to allow oil evaporation with steam while preventing thermal degradation of patchouli alcohol.

The condensed vapor is separated in a separator tank, filtered, and stored in stainless steel or epoxy-lined drums after decanting to prevent contamination (Rina *et al*., 2023). The final product must conform to SNI 06-2385-2006 standards, requiring a minimum 30% patchouli alcohol content, specific gravity of 0.950–0.975, refractive index of 1.507–1.515, and satisfactory organoleptic characteristics, parameters that determine the oil's eligibility for cosmetic, perfume, and pharmaceutical applications in the global value chain.

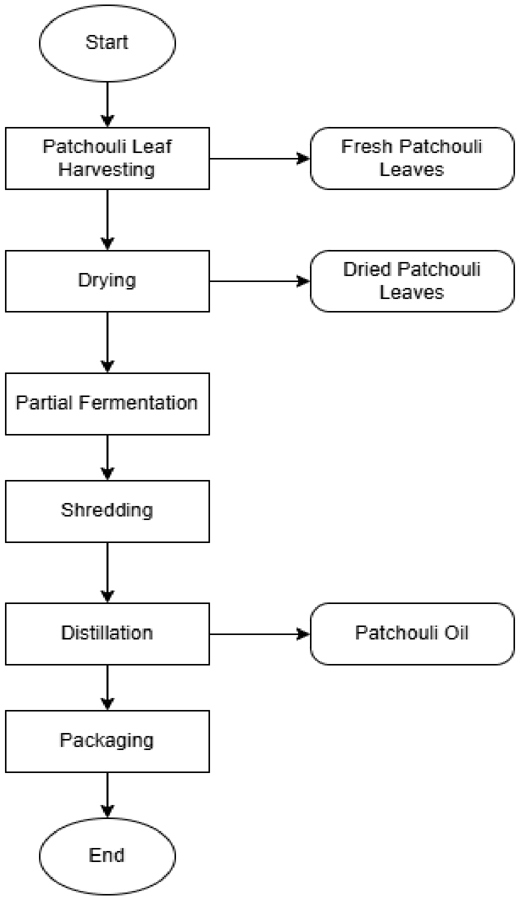

Figure 2. Patchouli oil production process from leaf harvesting to the final product

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Analysis of Patchouli Leaf Conversion

The conversion of patchouli leaves into essential oil involves substantial weight reduction at each processing stage, as summarized in Table 2. Drying alone reduces the fresh leaf weight by 75–80%, whereas distillation further reduces the dried material to yield only 0.005–0.0075 kg of oil per kg of fresh leaves. These significant shrinkage rates confirm that drying consistency, shredding, and distillation conditions are critical determinants of oil yield; in particular, shredding prior to distillation increases the material surface area, reducing extraction time and energy consumption (Nisa *et al*., 2024).

Current conversion rates reveal that productivity remains low under prevailing practices, indicating that greater control over raw material preparation, more consistent post-harvest handling, and distillation conditions aligned with industrial quality standards can enhance the value-added potential. Improving conversion efficiency would directly strengthen the competitiveness of patchouli products across the medicinal, cosmetic, and perfume sectors and increase income for village cooperatives.

Analysis of the Patchouli Agroindustry Supply Chain Network

Farmers are the primary and sole source of raw materials for the patchouli agroindustry in Sukabumi Regency, and they play a decisive role in determining the initial product quality. At the optimal harvest window of 6–7 months, farmers collect fresh patchouli leaves and pass them to fellow farmer group members for natural drying, a preparatory step that transforms fresh leaves into standardized, transportable, and distillation-ready material. From this point, dried leaves can follow one of two pathways: being sold to collective traders through the existing channel or being channeled to village cooperatives as the proposed alternative. This bifurcation is the central structural dynamic of the supply chain, as the chosen pathway directly determines how much value farmers ultimately derive from their produce and how equitably the benefits are distributed across the chain.

As illustrated in Figure 3, village cooperatives occupy the proposed central node of the supply chain, receiving dried leaves from farmer groups for cooperative-based distillation of patchouli oil. This cooperative processing enables value-added transformation, opening access to multiple downstream markets. Local MSMEs can source patchouli oil to develop high-value derivative products such as cosmetics, aromatherapy products, perfumes, and wellness products, whereas processing industries can receive cooperative-supplied oil for further homogenization and large-scale market distribution, ultimately reaching exporters and end consumers.

Table 2. Patchouli leaf weight conversion rates at each processing stage in patchouli agroindustry system

Processing Stage	Output Weight (kg)	Shrinkage (%)
Fresh leaves	1.00	0
Drying	0.20 – 0.25	75 – 80
Distillation	0.005 – 0.0075	±97 – 98

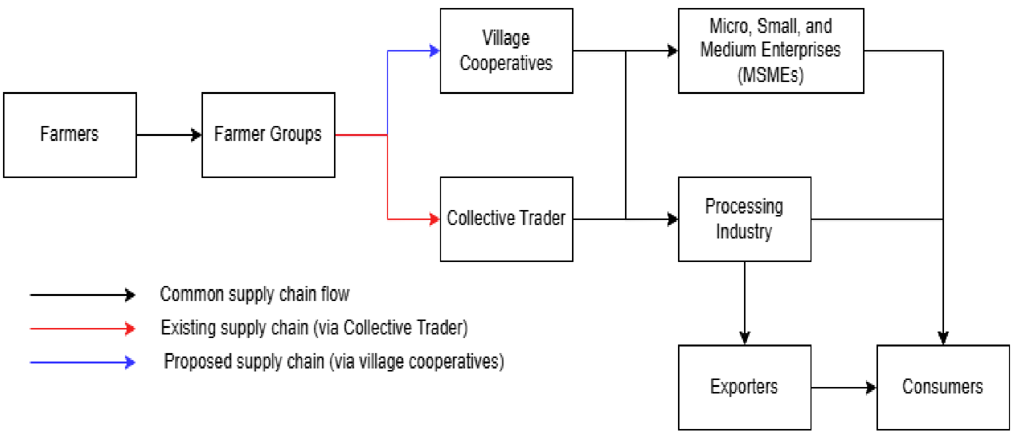

Figure 3. Proposed cooperative-centered supply chain network of the sustainable smart patchouli agroindustry

Village cooperatives are key sites for value-added production and quality control in the supply chain. By empowering cooperatives through institutional engagement with the Indonesian Essential Oil Council (*Dewan Atsiri Indonesia* — DAI) and strengthening linkages to MSMEs and processing industries, the patchouli agroindustry can reduce dependence on collector-based channels, enhance farmers' bargaining power, and ensure that patchouli oil products meet national and export-quality standards. These structural shifts, as reflected in the proposed supply chain flow in Figure 3, are essential for building a more efficient, transparent, and resilient agro-industrial industry.

SWOT Analysis of the Patchouli Agroindustry

A SWOT analysis was employed to assess the strategic position of the patchouli agroindustry in Sukabumi Regency by integrating internal and external factors derived from fieldwork, literature reviews, and global essential oil market analysis. Internal factors were structured as the Internal Factor Analysis Summary (IFAS), and external factors as the External Factor Analysis Summary (EFAS), with each factor quantitatively weighted and rated to produce an objective strategic positioning score (Rahman and Rahmah, 2018).

As shown in Table 3, the internal factor score totals 2.31, with weaknesses (1.25) outweighing strengths (1.06), indicating that internal constraints currently dominate the strategic position of the agroindustry. The primary strengths (Indonesia's dominance in the global patchouli market, institutional support from cooperatives and the DAI, and downstream potential through local MSMEs) provide a solid foundation for development. However, these are offset by high-scoring weaknesses, particularly traditional distillation technology with low efficiency and inconsistent quality standardization (both rated 0.40), compounded by weak cooperative managerial capacity and structural dependence on collectors. These vulnerabilities underscore the necessity of standardizing post-harvest procedures, modernizing distillation technology, and strengthening cooperative governance in the industry. A comparable cooperative empowerment model has been demonstrated in Konawe Regency, where Dzulkarnain *et al*. (2020) documented the establishment of Koperasi Nilam Samaturu (KIS) under a nucleus-plasma partnership scheme, positioning KIS as the central marketing entity for farmer-produced dried leaves and oils, a model relevant to the Sukabumi context.

As shown in Table 4, the external factor score totals 2.25, with opportunities (1.20) exceeding threats (1.05), thus reflecting a favorable external environment. Key opportunities include the high global demand for essential oils, government and DAI policy support, the growing trend toward natural and sustainable products, and the potential for supply chain digitalization through IoT and DSS. These are counterbalanced by significant threats, including global price fluctuations and market speculation (rated 0.40), climate change and environmental vulnerability, competition from other essential oil producers such as India, and the risks of deforestation and ecological degradation. Despite the favorable external landscape, capitalizing on these opportunities requires resolving internal weaknesses, particularly in terms of quality consistency, distillation efficiency, and cooperative governance.

Table 3. Internal Factor Analysis Summary (IFAS): weights and ratings of strengths and weaknesses of the patchouli agroindustry

Internal Factors	Weight	Rating	Weight × Rating
Strengths			
Indonesia’s dominance in the global patchouli market	0.10	4	0.40
Institutional support from cooperatives & DAI	0.10	3	0.30
Downstream potential through local MSMEs	0.08	3	0.24
Technical knowledge base & local practices	0.06	2	0.12
Subtotal Strengths			**1.06**
Weaknesses			
Traditional distillation technology with low efficiency	0.10	4	0.40
Inconsistent quality standardization	0.10	4	0.40
Weak cooperative managerial capacity	0.08	3	0.24
Dependence on collectors	0.07	3	0.21
Subtotal Weaknesses			**1.25**
Total (Internal)	1.00	—	**2.31**

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Table 4. External Factor Analysis Summary (EFAS): weights and ratings of opportunities and threats of the patchouli agroindustry

External Factors	Weight	Rating	Weight × Rating
Opportunities			
High global demand for essential oils	0.12	4	0.48
Government & DAI policy support	0.10	3	0.30
Growing trend of natural and sustainable products	0.08	3	0.24
Potential for supply chain digitalization (IoT, DSS)	0.06	3	0.18
Subtotal Opportunities			**1.20**
Threats			
Global price fluctuations and market speculation	0.10	4	0.40
Climate change & environmental vulnerability	0.08	3	0.24
Competition from other essential oil producers (India, etc.)	0.07	3	0.21
Risk of deforestation & ecological sustainability	0.05	4	0.20
Subtotal Threats			**1.05**
Total (External)	1.00	—	**2.25**

As illustrated in Figure 4, the strategic coordinates of the Sukabumi patchouli agroindustry are determined by calculating the difference between internal factor scores (Strengths – Weaknesses = 1.06 – 1.25 = –0.19) as the horizontal axis value and the difference between external factor scores (Opportunities – Threats = 1.20 – 1.05 = +0.15) as the vertical axis value. This coordinate of (–0.19; +0.15) places the agroindustry in Quadrant III (WO Strategy), a position characterized by internal weakness combined with a supportive external environment.

Figure 4. SWOT strategic positioning diagram of the patchouli agroindustry in Sukabumi Regency based on IFAS and EFAS scores

This positioning reflects a condition in which available market opportunities (including high global essential oil demand, government and DAI policy support, and digitalization potential) cannot be fully exploited because of inadequate internal capacity in distillation technology, quality standardization, and cooperative management. Therefore, strengthening these internal elements is a prerequisite for enabling village cooperatives and agroindustry actors to effectively capitalize on existing external opportunities.

Consistent with the Quadrant III positioning, WO strategies constitute the primary development priorities for the patchouli agroindustry. The three critical areas of intervention identified through the SWOT analysis are (1) modernization of distillation technology to improve processing efficiency and yield consistency, (2) establishment of uniform post-harvest handling and quality standards aligned with SNI–ISO requirements, and (3) strengthening of cooperative institutional capacity and governance to improve aggregation, value distribution, and supply chain coordination. These interventions directly address the dominant weaknesses identified in the IFAS and are essential for unlocking the external opportunities reflected in the EFAS.

Beyond WO priorities, the SWOT analysis indicates the importance of complementary, long-term strategies. SO strategies should leverage Indonesia's dominant market position and DAI institutional support to strengthen downstream processing and expand market linkages. ST strategies should focus on building product differentiation through quality improvement, organoleptic consistency, and branding "sustainable patchouli oil" to counteract global price fluctuations and competition from other producing countries. WT strategies should address climate vulnerability, ecological sustainability risks, and structural dependence on collectors through diversification and sustainable land management practices (Supayanti *et al*., 2023). Collectively, these strategic directions form the analytical foundation that is translated into the

Business Model Canvas framework in the following section.

Design of the Business Model Canvas for the Patchouli Agroindustry

The Business Model Canvas (BMC) for the patchouli agroindustry was constructed using nine key components, drawing upon the outputs of value chain and SWOT analyses to ensure that the resulting framework was empirically grounded and strategically aligned (Hidayat *et al*., 2021; Bahayyil *et al*., 2025). As widely demonstrated in agroindustrial and cooperative-based studies, the BMC serves as a strategic tool for systematically translating analytical findings into an integrated and actionable business model (Casnan *et al*., 2022). The complete canvas is shown in Figure 5.

As shown in Figure 5, the WO strategies derived from the SWOT analysis directly inform the BMC's value creation logic. The primary customer segments are essential oil industries and exporters requiring a consistent, large-volume supply, supported by local MSMEs producing derivative products, and end consumers valuing natural and sustainable goods. The core value propositions include high-quality patchouli oil compliant with SNI–ISO standards, stable cooperative-coordinated pricing, supply chain traceability enabled by digitalization, and branding of "sustainable patchouli oil." Distribution is facilitated through direct agreements with industries and exporters, DAI and government institutional partnerships, MSME marketplaces, and digital B2B platforms serving both domestic and international markets.

Referring to Figure 5, the BMC's key activities encompass the collection, drying, distillation, quality standardization, and packaging of patchouli leaves, supported by farmer institutional strengthening, cooperative manager and technician training, downstream product development through partner MSMEs, and export branding. Key resources include farmer-supplied raw patchouli leaves, cooperative-owned steam distillation facilities, quality testing infrastructure, trained cooperative human resources, and digital platforms for supply chain monitoring and transparency incorporating IoT and DSS as digitalization instruments identified through SWOT analysis. Customer relationships are maintained through long-term contractual arrangements with industries and exporters, technical support for partner MSMEs, and digital price transparency services.

As detailed in Figure 5, key partners include essential oil exporters, the global fragrance and cosmetics industries, local MSMEs, the DAI, regional government agencies, certification bodies, and sustainability-oriented partners, all of whom collectively enable quality improvement, market expansion, and premium pricing access. The cost structure includes raw material procurement, distillation operations, packaging and quality standardization, cooperative management and training, supply chain digitalization investment, and marketing expenses.

<table>
<tr><td rowspan="2">Business Model Canvas</td><td>Designed for:</td><td>Designed by:</td><td>Date:</td><td>Version:</td></tr>
<tr><td>Sustainable and Smart Patch
Agroindustry</td><td>Firman Arief Soejana</td><td>20 August 2025</td><td>1</td></tr>
</table>

<table>
<tr><td>Key Partners</td><td>Key Activities</td><td rowspan="4">Value Propositions
• High-quality patchouli oil compliant with SNI and ISO standards
• Natural and sustainable value-added products (eco-friendly)
• Stable pricing through village cooperative mechanisms and DAI support
• Supply-chain transparency enabled by digitalization (IoT, DSS, optional blockchain)</td><td>Customer Relationships</td><td rowspan="4">Customer Segments
• Essential oil processing industries (primary target)
• Essential oil exporters
• Local MSMEs (aromatherapy, soap, perfume, herbal products)
• End consumers of value-added products (domestic & global through MSMEs/industry)</td></tr>
<tr><td rowspan="3">• Essential oil exporters
• Global fragrance, cosmetics, and pharmaceutical industries
• Local MSMEs producing patchouli-based value-added products (aromatherapy, soap, herbal products)
• End consumers of value-added products (domestic & international)</td><td>• Collection and drying of patchouli leaves
• Patchouli oil distillation process
• Quality standardization and packaging
• Farmer training and strengthening of cooperative institutions
• Downstream product development through partner MSMEs
• Branding and export marketing</td><td>• Long-term contractual relationships with industries and exporters
• Technical support and quality training for partner MSMEs
• Cooperative-based patchouli farmer community
• Digital services for price transparency for farmers</td></tr>
<tr><td>Key Resources</td><td>Channels</td></tr>
<tr><td>• Raw patchouli leaves supplied by farmers
• Cooperative-owned distillation facilities (steam distillation, condenser, boiler technologies)
• Quality standards (basic laboratory facilities/quality testing partnerships)
• Cooperative human resources (management, distillation operators, technicians)
• Digital platforms for supply-chain monitoring and transparency</td><td>• Direct sales from the cooperative to industries/exporters
• Cooperative partnerships with DAI and government institutions
• Marketplaces for MSME value-added products
• Trade fairs and digital promotion (e-commerce, global B2B platforms)</td></tr>
</table>

<table>
<tr><td>Cost Structure</td><td>Revenue Streams</td></tr>
<tr><td>• Procurement cost of patchouli leaves from farmers
• Distillation operational costs (energy, labor, machinery maintenance)
• Packaging and quality standardization costs
• Cooperative management and training expenses
• Investment in supply-chain digitalization
• Marketing and distribution costs (local & export)</td><td>• Sales of cooperative-produced patchouli oil
• Sales of value-added products through MSMEs (profit-sharing scheme)
• Premium pricing derived from quality standards and “sustainable patchouli oil” branding
• Potential CSR funds/green financing from sustainability-oriented partners.</td></tr>
</table>

Figure 5. Business model canvas of the cooperative-centered sustainable smart patchouli agroindustry development system

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Revenue is primarily generated from cooperative-produced patchouli oil sales, complemented by MSME value-added product profit sharing, premium pricing from sustainable branding, and potential CSR and green financing. Collectively, this BMC reflects a capacity-oriented cooperative model that reinforces institutional strength, quality consistency, and technological advancement as the foundation for sustainably capturing global patchouli oil market opportunities.

Design of the Smart Patchouli Agroindustry System

The proposed smart system operationalizes the BMC and WO strategies derived from the SWOT analysis, with each module traceable to specific BMC blocks and SWOT factors addressing identified internal weaknesses and external opportunities. The architecture is a single integrated platform with role-based access, in which each actor interacts through a dedicated module while sharing common data and traceability infrastructure. It comprises four layers: the actor layer, the platform layer with seven role-based modules, the data layer (database, blockchain node, and analytics engine), and the external integration layer (laboratories, government, and global market APIs). The complete architecture is shown in Figure 6.

The farmer module enables the digital recording of seed variety, cultivation activities, and harvest data, addressing low digital literacy and information asymmetry between producers and intermediaries (Mushi *et al*., 2024; Wang *et al*., 2025). The DAI module delivers good agricultural practice (GAP) standards, training schedules, and compliance monitoring, converting institutional support into continuous capacity building, a decisive enabler of cooperative digital transformation (Zheng *et al*., 2024). The cooperative management module digitalizes aggregation, stock, distillation, and member administration, anchoring the village cooperative as the central institutional actor; cooperative-owned platforms have been shown to outperform externally owned ones in protecting smallholder interests (Dawson *et al*., 2024; Santos *et al*., 2024).

As further illustrated in Figure 6, the laboratory module connects KAN-accredited laboratories to upload patchouli alcohol (PA) test results and SNI–ISO certificates, transforming subjective quality assessment into laboratory-grounded data; Industry 4.0 integration in essential oil distillation has been shown to improve yield by up to 24% and quality by 10% (Machado *et al*., 2024). The decision support system (DSS) serves as the analytical core and automatically determines a fair reference price by combining laboratory-verified PA content, market signals via API, and a government-mandated base price, thereby replacing exploitative *tengkulak* pricing with a transparent mechanism (Müller *et al*., 2022; Casado-Vara *et al*., 2021).

The B2B marketplace module connects the cooperative directly to industries, exporters, and MSMEs, bypassing intermediaries. E-commerce adoption among smallholders has been shown to improve market access, increase prices received, and reduce post-harvest losses (Ogundeji *et al*., 2024).

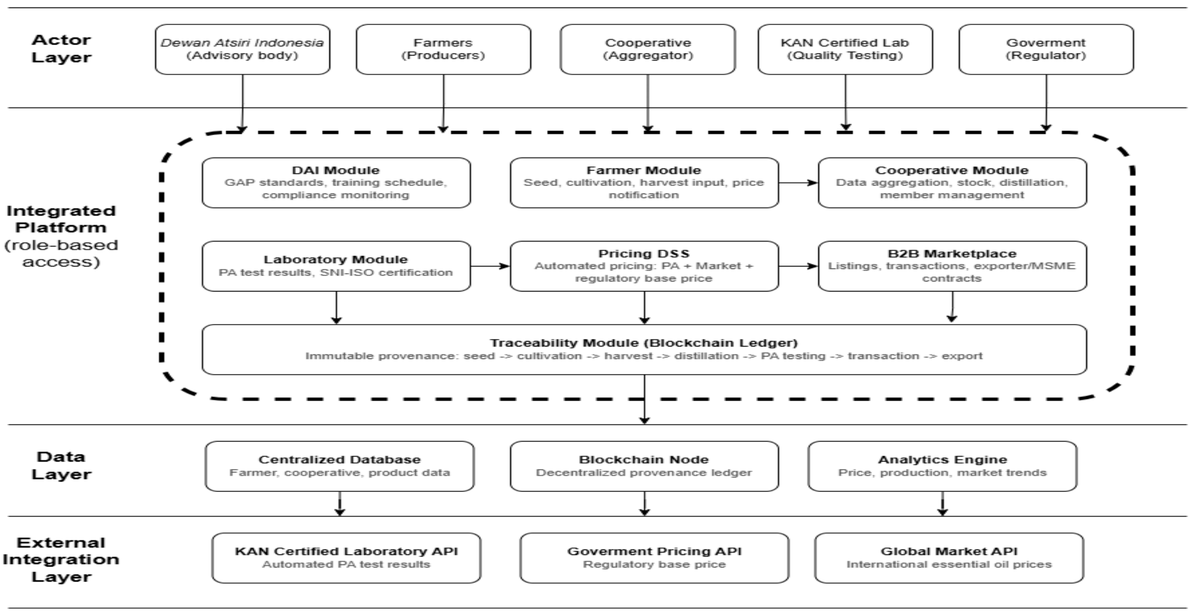

Figure 6. Layer architecture model of the smart system for the sustainable patchouli agroindustry development in Sukabumi Regency

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The traceability module uses a blockchain-based ledger to record an immutable end-to-end provenance history, from seed origin and cultivation to distillation, laboratory testing, transactions, and export, addressing the growing demand for traceable sustainable products (Bosona and Gebresenbet, 2023; Vitaskos *et al*., 2024; Gonçalves *et al*., 2025). As shown in Figure 6, all modules feed verified data into a shared data layer and connect to external APIs for laboratory results, government pricing references and global market benchmarks (Sánchez-Cañizares *et al*., 2022).

Managerial Implications for Sustainable Patchouli Agroindustry

The proposed smart system delivers concrete positive impacts across all stakeholders by simultaneously addressing the economic and social dimensions of sustainability. Economically, the system replaces opaque intermediary-driven price formation with quality-based pricing, increasing farmer income and reducing transaction costs through direct B2B linkages, mechanisms empirically shown to improve smallholder welfare in digitalized agri-food chains (Ma and Abdulai, 2023; Ji *et al*., 2024). Socially, the cooperative anchors collective bargaining, transfers chain ownership to local producers, and embeds continuous capacity building through DAI partnerships, patterns well-documented in the literature as drivers of rural empowerment and inclusive development (Ma *et al*., 2023; Rostami and Salehi, 2024). The actor-specific implications are presented in Table 5.

Table 5. Managerial actions and sustainability impacts of key actors in the sustainable smart patchouli agroindustry development system

Actor	Managerial action	Sustainability impact (economic & social)
Farmers	Adopt digital recording of cultivation data and follow GAP standards facilitated by DAI; engage actively in the cooperative as members rather than as price-takers vis-à-vis *tengkulak*.	Economic: fairer, quality-based prices and stable income; reduced exposure to predatory intermediaries (Wang *et al*., 2025). Social: improved digital literacy, stronger bargaining position, and dignity through formalized roles in collective decision-making (Ma *et al*., 2023).
Cooperative	Establish governance and operational structure; manage aggregation, distillation, member data, and platform onboarding; coordinate with DAI on training delivery.	Economic: economies of scale in distillation and marketing; access to premium markets through aggregated supply (Dawson *et al*., 2024). Social: community-owned institution that retains value locally and fosters trust, gender inclusion, and collective resilience (Suresh *et al*., 2024).
DAI & Government	Issue and enforce a quality-based regulatory base price; deliver continuous GAP training; designate KAN-accredited laboratories; provide policy and financing support for cooperative digital transformation.	Economic: strengthened national position in the global essential oil market and improved tax/export revenue traceability (Zheng *et al*., 2024). Social: institutional legitimacy, rural development, and reduced regional inequality through inclusive policy infrastructure (Rostami and Salehi, 2024).
Exporters	Source patchouli oil through verified, traceable contracts via the B2B marketplace; rely on blockchain-based provenance for buyer due diligence and sustainability claims.	Economic: lower compliance and verification costs; access to differentiated, premium-priced sustainable patchouli oil (Bosona and Gebresenbet, 2023). Social: credible alignment with global ESG and ethical sourcing expectations, strengthening long-term buyer–supplier relationships (Vitaskos *et al*., 2024).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study concludes that the patchouli agroindustry in Sukabumi Regency requires three integrated strategic interventions: (1) strengthening village cooperatives as key institutions for aggregation, processing, and value-chain coordination, (2) modernizing distillation technology to improve oil yield, process efficiency, and product consistency, and (3) establishing uniform post-harvest and quality standards aligned with SNI–ISO requirements. These strategic priorities are consistently identified through the three analytical approaches employed in this study—value chain analysis, SWOT analysis, and the Business Model Canvas (BMC). They are further supported by the proposed smart agroindustrial system, which integrates the Internet of Things (IoT), a Decision Support System (DSS), blockchain-based traceability, and a business-to-business (B2B) marketplace to improve transparency, operational efficiency, supply-chain coordination, and farmers' bargaining power while responding to growing global demand for natural and sustainably produced products. Collectively, the findings provide an integrated conceptual and practical framework for the development of a smart, inclusive, and sustainable patchouli agroindustry in Indonesia.

Recommendations

Future research should focus on three priority areas. First, the development and commercialization of high-value-added derivative products including cosmetics, aromatherapy, and pharmaceutical products, through cooperative-linked networks of micro, small, and medium-sized enterprises (MSMEs) should be investigated to enhance downstream value creation and value capture. Second, multi-stakeholder governance frameworks should be developed and empirically evaluated to clearly define institutional roles, coordination mechanisms, and equitable benefit-sharing arrangements among farmers, cooperatives, distillers, industry actors, and government agencies. Third, the potential of green financing instruments and corporate social responsibility (CSR) funding should be explored to accelerate the digital transformation of cooperatives and support environmentally sustainable production practices. Together, these research directions could strengthen the environmental, social, and economic sustainability of the Indonesian patchouli agroindustry while enhancing its competitiveness in global markets.

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