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# Determination of sustainability status and sensitive factors in clove farming

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***Abstract*---**Changes in socio-economic conditions and the advancement of agricultural technology have created challenges to the sustainability of clove farming in Madenan Village, Tejakula District, Buleleng Regency. This study aims to analyze the sustainability status of clove farming within the *Subak Abian* system and to identify the sensitive factors influencing its sustainability. Both quantitative and qualitative data were collected through questionnaires, interviews, and literature reviews. The data were analyzed using the Multiaspect Sustainability Analysis (MSA) method, which encompasses five dimensions: ecological, economic, socio-cultural, institutional, and technological. The results reveal that the sustainability index value of clove farming in *Subak Abian* is 57.09, indicating a sustainable category. Each dimension exhibits varying levels of sustainability: ecological (39.29 – low sustainable), economic (62.50 – sustainable), socio-cultural (70.29 – sustainable), institutional (56.25 – sustainable), and technological (57.14 – sustainable). The sensitive factors influencing sustainability include farmers' understanding of soil and water conservation, payment systems for harvested products, the existence of social farmer groups, agricultural extension and machinery support institutions, and the adoption of cultivation technologies—particularly the one-shoot (single-bud) pruning method. Scenario analysis suggests that the most effective improvements can be achieved through Scenario 2 for the ecological and institutional dimensions, and Scenario 1 for the economic, socio-cultural, and technological dimensions. Recommended strategies include strengthening farmers' knowledge of soil and water conservation, enhancing fair and transparent clove marketing systems, reactivating


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agricultural extension and farmer cooperative institutions, and expanding the adoption of modern cultivation technologies adapted to local conditions. These efforts are expected to foster a resilient, competitive, and sustainable clove farming system in alignment with the *Tri Hita Karana* philosophy and the Sustainable Development Goals (SDGs), particularly Goals 1, 2, 8, 12, and 15.

***Keywords*---***Subak Abian*, sustainability, clove farming, agribusiness, MSA, *Tri Hita Karana.*

## Introduction

Indonesia is one of the world's largest producers and exporters of cloves, with an annual production of 137.64 thousand tons in 2021, of which 98.59% originated from smallholder plantations (FAO, 2022). Besides contributing significantly to the global market, domestic demand for cloves continues to increase at an annual rate of 6.27%, projected to reach 130.66 thousand tons by 2026 (Darmawan, 2022). In Bali, Buleleng Regency is the leading clove-producing area, contributing approximately 4.1 thousand tons in 2024 (BPS Buleleng, 2024). This commodity plays a crucial role in strengthening the local economy and supporting rural livelihoods.

The traditional agricultural system in Bali, known as *Subak*, reflects the *Tri Hita Karana* philosophy, emphasizing harmony among humans, nature, and spirituality (Ardana et al., 2024). This concept extends beyond irrigated rice fields to dryland farming systems through *Subak Abian*, a local institution that manages plantation crops such as cloves and coffee. *Subak Abian* has historically preserved ecological balance and social cohesion while supporting sustainable livelihoods in rural Bali.

Madenan Village, located in Tejakula District, is recognized as one of the main clove-producing centers within *Subak Abian*. However, despite its economic significance, the sustainability of clove farming in this area faces several challenges. Economically, the prevalent *tebasan* (forward payment) system limits farmers' bargaining power and income stability, as prices are determined before harvest and payments are often delayed (Hardian et al., 2024; Yuniari, 2017). Technologically, many farmers still rely on traditional cultivation methods, such as maintaining excessive shoot growth, which reduces productivity and efficiency (Sugiyatno et al., 2020; Wijaya et al., 2015).

Ecological concerns also arise from the lack of soil and water conservation practices on sloping lands, leading to declining soil fertility and increased erosion risks (Hakim, 2021; Sukarman et al., 2021). Institutionally, *Subak Abian* lacks adequate farmer cooperatives and agricultural machinery service units, limiting efficiency and access to modern tools (Indrayanti et al., 2024; Endaryanto et al., 2025). Furthermore, socio-cultural changes, such as the decline of traditional *seka penggarap* labor groups, have weakened communal cooperation and social solidarity (Puspita et al., 2024).

Therefore, assessing the sustainability of clove farming in *Subak Abian* requires a multidimensional approach that integrates ecological, economic, socio-cultural, institutional, and technological aspects. Such an approach aligns with the global agenda of the Sustainable Development Goals (SDGs), particularly Goals 1 (No Poverty), 2 (Zero Hunger), 8 (Decent Work and Economic Growth), 12 (Responsible Consumption and Production), and 15 (Life on Land). This study aims to evaluate the sustainability status of clove farming and identify sensitive factors influencing its sustainability in *Subak Abian*, Madenan Village, Buleleng Regency.

## Literature Review

*Ecological Aspect*
Sustainability in agricultural systems depends heavily on ecological integrity, particularly soil and water conservation. According to Hakim (2021), farming practices that ignore conservation measures—such as terracing, contour bunding, and cover cropping—can lead to severe soil erosion, reduced fertility, and diminished water-holding capacity. Similar findings by Sukarman et al. (2021) reveal that unprotected sloping lands are vulnerable to topsoil loss and degradation of productive capacity. In dryland ecosystems such as *Subak Abian*, ecological degradation not only threatens crop productivity but also disrupts the balance between humans and nature central to the *Tri Hita Karana* philosophy. Implementing soil and water conservation technologies, therefore, becomes crucial to maintaining long-term agricultural sustainability.

*Economic Aspect*
Economic sustainability in clove farming is influenced by market mechanisms, income distribution, and farmers' bargaining positions. The *tebasan* system, characterized by advance payments and deferred settlements, often results in price distortions and income insecurity for farmers. Hardian et al. (2024) note that such practices reduce farmers' profit margins as collectors gain more from price differences between the pre-harvest agreement and market value. Yuniari (2017) also found that intermediaries and exporters capture higher profit margins than farmers, highlighting an imbalance in the clove value chain. Limited financial literacy and weak cooperative institutions exacerbate dependency on middlemen, reducing farmers' ability to reinvest in production inputs and adopt sustainable agricultural innovations.

*Socio-Cultural Aspect*
The socio-cultural dimension of sustainability emphasizes collective action, local wisdom, and community solidarity. Traditional systems such as *seka penggarap*, which promote mutual assistance during harvest, have long supported labor sharing and social cohesion among *Subak* members (Puspita et al., 2024). However, modernization has led to the replacement of these communal systems with wage-based labor from outside villages. This transition, while increasing flexibility, erodes social capital, weakens community ties, and diminishes local participation in agricultural management. Upholding traditional values of *gotong royong* (cooperation) remains essential to strengthening social resilience and cultural sustainability within rural farming communities.

*Institutional Aspect*
Institutional structures play a pivotal role in facilitating sustainable agricultural practices by providing access to resources, tools, and knowledge. The absence of specialized institutions managing agricultural machinery (*alsintan*) in *Subak Abian* reduces operational efficiency and increases production costs. Indrayanti et al. (2024) reported that access to mechanization services through farmer cooperatives can significantly improve productivity and cost efficiency. Similarly, Endaryanto et al. (2025) observed that regions with active farmer organizations and machinery service units achieve higher synchronization in planting and harvesting cycles, enhancing overall agribusiness performance. Therefore, strengthening institutional capacity through cooperative-based mechanisms is fundamental for the long-term sustainability of smallholder farming systems.

*Technological Aspect*
Technological innovation is a critical determinant of agricultural productivity and environmental efficiency. Many clove farmers in *Subak Abian* still rely on traditional cultivation practices, such as maintaining excessive shoots, assuming this increases yield. However, research by Sugiyatno et al. (2020) demonstrated that optimal pruning techniques improve photosynthate distribution and reduce pest infestation risks. Similarly, Wijaya et al. (2015) found that the adoption of modern agronomic practices—such as controlled pruning and nutrient management—leads to significant improvements in both yield and product quality. The slow adoption of innovation among farmers reflects limited access to agricultural extension, low technological literacy, and risk aversion, all of which hinder the transition toward sustainable clove farming systems.

## Methods

This study was conducted in the *Subak Abian* of Madenan Village, Tejakula District, Buleleng Regency (Bali) from September to December 2025. The site was purposively selected as a major clove-producing center (≈22 tons in 2024) that currently exhibits production stagnation and multidimensional sustainability challenges. The research adopted a descriptive–quantitative design supported by qualitative evidence to assess sustainability across five dimensions—ecological, economic, socio-cultural, institutional, and technological—using the Multiaspect Sustainability Analysis (MSA) approach. Data comprised primary sources (questionnaires, in-depth interviews, focus group discussions, direct observation) and secondary sources (government statistics, regulations and *awig-awig*, prior studies, institutional documents).

Informants were selected through purposive sampling, emphasizing expert and stakeholder perspectives consistent with MSA practice. The final sample consisted of 13 key informants representing the plant-pest controller (POPT), agricultural extension officer (PPL), village head, *pekaseh*, three *klian tempek*, and six farmers (each owning at least three plot locations). Instruments included a structured questionnaire capturing ordinal indicators for each dimension, interview and FGD guides for qualitative elaboration, and observation/documentation checklists. Each dimension was operationalized into scored indicators (0 = poor to maximum = good) aligned with national standards, ministerial decrees, local *awig-awig*, and prior research; examples include soil–water conservation, pest and disease

management, payment and marketing systems, the presence and activity of cooperatives and extension services, and the adoption of cultivation technologies. Data analysis followed MSA procedures implemented with EXSIMPRO (a derivative of RAPFISH), involving indicator normalization, computation of dimension scores (0–100), and aggregation into an overall sustainability index. Status thresholds applied were 0–25 (Unsustainable), >25–50 (Low Sustainable), >50–70 (Sustainable), and >75–100 (Very Sustainable). Leverage analysis was used to identify sensitive factors with the greatest influence on index changes, while scenario analysis compared improvement options—such as a socio-economic/technological emphasis (Scenario 1) versus ecological/institutional integration (Scenario 2)—based on expected index gains. Robustness was checked through uncertainty assessment with an error limit of ~10% and random-iteration validation against modal expert scores. Ethical protocols included informed consent, confidentiality, and respect for local customs within the *Subak Abian* system, with content validity ensured through expert judgment and overall credibility strengthened via triangulation across methods and sources.

## Result and Discussion

*Sensitive Factors*

MSA findings reveal a concentrated set of sensitive factors that disproportionately shape the sustainability of clove farming in *Subak Abian*, Madenan. Leverage analysis across ecological, economic, socio-cultural, institutional, and technological dimensions points to practical, high-impact levers that are both technically actionable and institutionally feasible, thereby offering a clear basis for prioritizing interventions and sequencing reforms.

Ecologically, two elements dominate the leverage structure: farmers' understanding and application of soil–water conservation and the configuration of land use in line with site capability. On the sloping, rain-fed orchards typical of Subak Abian, weak conservation practice accelerates runoff and topsoil loss, depressing plant vigor and long-term productivity. Strengthening farmer knowledge and practice—through terracing, vegetative strips, cover crops, mulching, and drainage/rorak—emerges as the fastest pathway to lift the ecological index. Land-use discipline that standardizes selected mother trees and varietal uniformity acts synergistically, stabilizing yield and plant health and amplifying the gains from conservation. Complementary integrated pest and disease management protects these improvements by suppressing pressure from pests and white-root diseases.

Economically, the payment system used by collectors—*tebasan/ijon* with deferred settlements—is the most sensitive factor because it directly constrains cash flow, bargaining power, and reinvestment capacity. Farm-gate prices form the second major lever and interact closely with payment terms: volatility magnifies liquidity risk under deferred payments and entrenches dependence on advance financing. Economic sustainability therefore hinges on shifting toward cash-at-delivery mechanisms mediated by farmer organizations, instituting transparent price discovery and collective marketing, and improving postharvest handling—drying and grading in particular—to access higher price tiers. These measures dampen exposure to volatility and reduce structural disadvantage in local oligopsonies.

From a socio-cultural standpoint, revitalizing *seka penggarap*—the traditional harvest mutual-aid groups—is the strongest lever. The erosion of these groups has raised hired-labor costs while weakening social cohesion, knowledge sharing, and resilience. Increasing family participation across production activities and decision-making further reinforces intra-household labor flexibility, intergenerational learning, and the collective norms that previously underpinned the *seka* model. Rebuilding this bonding social capital is closely associated with higher adoption of good practices and more reliable coordination at harvest time.

Institutionally, establishing a farm-machinery service unit (*alsintan*/UPJA) is the pivotal lever because it ensures timely, cost-efficient field operations and reduces slippage in planting and harvesting calendars. A farmer cooperative functions as the complementary backbone that links inputs, machinery management, collective selling, and financial intermediation. Where these institutions are absent or inactive, costs rise and market power deteriorates; when they are active, mechanization, pooled procurement, cash-based marketing, and access to micro-finance become feasible, multiplying the effects of technological and economic upgrades.

Technological levers are led by the adoption of modern cultivation practices—especially regular pruning and canopy management, nutrient alignment, and GAP-consistent spacing—which translate directly into more uniform flowering, higher essential-oil content, lower pest and disease incidence, and more efficient harvesting. Operational mastery of tools, from pruning equipment to safe harvest systems, is the enabling condition for these practices; without skills and access, technology recommendations do not take root. Institutional scaffolding through UPJA and cooperatives provides the training, shared assets, and routines that convert recommendations into routine practice.

Taken together, the sensitive factors form a coherent pathway for improvement. Ecological knowledge and land-use discipline safeguard the resource base; technological upgrades convert that base into yield and quality; institutional scaffolding delivers timely operations, pooled inputs, cash marketing, and finance; socio-cultural revitalization restores low-cost labor mobilization and collective problem-solving; and economic reforms to payment terms and pricing lock in income stability. This alignment mirrors the study's scenario logic, where ecological–institutional strengthening complements socio-economic and technological upgrades; sequencing both strands together maximizes gains in the aggregate sustainability index and produces a more resilient, competitive, and community-anchored clove farming system.

*Sustainability Status Improvement Scenarios*

The improvement scenarios demonstrate a clear enhancement in the sustainability performance of clove farming in *Subak Abian*, Madenan Village, where the composite index increased from 57.09 (sustainable) in the existing condition to 76.96 (very sustainable) in Scenario 1 and 92.52 (very sustainable) in Scenario 2. These results indicate that the combination of short- to medium-term operational improvements in Scenario 1 and structural long-term reinforcement in Scenario 2 complement each other effectively. The change ratio (ΔS2S/ΔS1S) shows that the ecological and institutional dimensions are more effectively

improved through the long-term and structural interventions of Scenario 2, while the economic, socio-cultural, and technological dimensions respond more rapidly to the managerial and operational interventions of Scenario 1.

In the **ecological aspect**, Scenario 1 focuses on enhancing farmers' understanding of soil and water conservation and improving land-use practices, raising the score from 39.29 to 58.29. Scenario 2 then optimizes land-use standardization, seedling availability, and pest-disease control through the adoption of conservation techniques, topographic zoning, cover crops, and agroforestry, further increasing the score to 77.43. In the **economic aspect**, Scenario 1 transforms the payment system from deferred to cash-based and secures farm-gate prices through transparent pricing, collective contracts, and better postharvest handling, elevating the score from 62.50 to 81.25. Scenario 2 strengthens marketing systems and professionalizes farmers' status within the agribusiness value chain, raising the score to 95.88. The **socio-cultural aspect** under Scenario 1 revitalizes *seka penggarap* (traditional labor groups) and increases family participation to reduce labor costs, strengthen cohesion, and accelerate the adoption of best practices, lifting the score from 70.29 to 91.71. Scenario 2 enhances farmers' experience and educational attainment, bringing the score to 96.43. The **institutional aspect** in Scenario 1 establishes and operationalizes machinery service units (UPJA) and reactivates basic extension services, improving the score from 56.25 to 75.00, while Scenario 2 consolidates extension, cooperative, and microfinance institutions to achieve a perfect score of 100. Finally, the **technological aspect** in Scenario 1 encourages the application of modern cultivation technology—such as pruning and canopy management—and strengthens farmers' operational mastery of tools, increasing the score from 57.14 to 78.57. Scenario 2 further reinforces the system through improvements in farm road infrastructure and the provision of harvesting machinery, leading to a final score of 92.86.

Overall, the most efficient improvement pathway begins with the rapid actions under Scenario 1 in the economic, socio-cultural, and technological dimensions—cash payment systems and transparent marketing, revitalized *seka penggarap* and family involvement, and the adoption of pruning and equipment operation—which directly improve cash flow, labor efficiency, and productivity. These short-term gains are then secured by Scenario 2 through landscape-based soil and water conservation, standardized land use and seed management, and institutional strengthening of extension services, cooperatives, UPJA, and financing mechanisms. This sequential integration explains the cumulative increase in the overall sustainability index from 57.09 to 76.96 and finally to 92.52. A sustainable ecological foundation and robust institutional framework stabilize economic and technological gains, while the revitalization of social capital ensures continued collective coordination and long-term resilience in the clove farming system of *Subak Abian*, Madenan Village.

## Conclusion

The sustainability status value of clove farming in *Subak Abian*, Madenan Village, was found to be 57.09, categorized as sustainable. Each dimension demonstrated varying sustainability levels: the ecological aspect scored 39.29 (low sustainable);

the economic aspect scored 62.5 (sustainable); the socio-cultural aspect scored 70.29 (sustainable); the institutional aspect scored 56.25 (sustainable); and the technological aspect scored 57.14 (sustainable). The most sensitive attributes influencing each dimension were also identified. The key leverage factor for the ecological aspect is farmers' understanding of soil and water conservation. For the economic aspect, the most influential attribute is the payment system applied by collectors. In the socio-cultural aspect, the most sensitive attribute is the existence of social groups such as *seka penggarap* (traditional harvest labor groups). The institutional aspect is primarily influenced by the presence and functionality of agricultural machinery institutions (*alsintan*), while the technological aspect is most affected by the adoption of cultivation technology concepts.

The sustainability status improvement scenarios were carried out across all five dimensions using two scenarios and two driving factors. The results showed that the sustainability index of clove farming in *Subak Abian*, Madenan Village, improved significantly—from the existing condition (57.09, sustainable) to 76.96 (very sustainable) under Scenario 1, and further to 92.52 (very sustainable) under Scenario 2. These findings confirm that Scenario 1 contributes to short- and medium-term improvements, while Scenario 2 reinforces long-term sustainability through structural and institutional enhancement.

*Recommendations*

1. Enhancement of the Ecological Aspect
   Given that ecology achieved the lowest sustainability score, efforts should prioritize strengthening farmers' knowledge and awareness of soil and water conservation. This dimension has a significant influence on the sustainability of the entire farming system. The limited application of conservation techniques—such as terracing, organic mulching, and proper drainage—accelerates land degradation and reduces clove productivity. The integration of mulching and terrace reinforcement has been proven to minimize soil and water loss in sloped areas, making it highly relevant for *Subak Abian* landscapes with hilly topography. Knowledge serves as a key livelihood asset that drives the adoption of conservation technologies among farmers. Therefore, it is necessary to reinforce the implementation of Law No. 37 of 2014 on Soil and Water Conservation as the legal foundation for land resource management and encourage the formulation of derivative regional regulations. Local governments and agricultural extension agencies should develop capacity-building programs, expand farmers' access to conservation technologies (mulch, terraces, drainage), and improve the effectiveness of field demonstrations and training programs.
2. Strengthening Multi-Stakeholder Collaboration
   Sustainability efforts require synergy between internal stakeholders (*krama subak*) and external partners, such as local governments, research institutions, universities, and private agricultural input providers. These collaborations should focus on technical assistance, provision of production facilities, postharvest equipment, and continuous training to enhance farmers' technical capacity. Periodic monitoring and evaluation—

particularly through demonstration plots—should be conducted to assess the effectiveness of innovation implementation at the field level.

3. Future Research Development
   This study acknowledges certain limitations, particularly in the depth of analysis across sustainability dimensions. Therefore, further studies are recommended to explore more specific and measurable interlinkages between dimensions, allowing the formulation of comprehensive and mutually reinforcing sustainability strategies. Future research should also examine the effectiveness of local policies and the role of *subak* institutions in supporting sustainable agricultural practices. Moreover, developing farmer empowerment models based on local wisdom and technological innovation in conservation practices will yield more applicable recommendations to strengthen the sustainability of clove farming in *Subak Abian* and other agricultural regions.

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