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# Variability of Soil Properties in Patchouli Cultivation Land in Sekerak District, Aceh Tamiang Regency, Aceh

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**Abstract.** Patchouli (*Pogostemon cablin* Benth.) cultivation in Sekerak District, Aceh Tamiang Regency, faces challenges related to soil fertility and quality. This study aims to determine the status of soil fertility and soil quality using the VESS method on patchouli cultivation land. The results showed that soil fertility at all study sites was low. The soil quality assessment results were good to moderate. These findings emphasize the need for optimal soil fertility management to increase sustainable patchouli production.

**Keywords**: *Aceh Tamiang, intercropping, monoculture, patchouli (Pogostemon cablin Benth.), Sekerak*

## 1. Introduction

Since 2022, Aceh Tamiang Regency has launched the Patchouli Cultivation Development Program as one of the region's flagship programs to improve community welfare. The strategic step is to involve communities across several sub-districts within Aceh Tamiang Regency in the patchouli planting program. By early 2025, the area of patchouli cultivation in Aceh Tamiang Regency was 852,40 ha, spread across seven sub-districts (Karang Baru, Sekerak, Manyak Payed, Rantau, Tenggulun, Bandar Pusaka, and Kejuruan Muda) [1].

Patchouli farmers in Aceh Tamiang Regency are cultivating patchouli monoculture (single crop). This condition can lead to land degradation, which will impact the land's carrying capacity and quality. This will reduce patchouli production and productivity. If these conditions are not properly managed, the patchouli development program in Aceh Tamiang Regency is at risk of failure.

This is because patchouli productivity is affected by inefficient agricultural practices, which lead to problems related to reduced air retention and infiltration, increased erodibility, and the risk of soil compaction, which causes resistance to penetration. Reduced pore space results in low gas and air flow, which inhibits root growth and development, increases the loss of fine particles, organic matter, and nutrients, and ultimately reduces soil quality, leading to soil degradation. Land degradation is irreversible, therefore proper land management is necessary to prevent land degradation and maintain soil quality. Furthermore, remediating degraded lands can contribute to Sustainable Development Goal (SDG) 15, which aims to protect, restore, and sustainably manage land-based ecosystems, specifically aiming to achieve a world free from land degradation by 2030 [2].

Land degradation is the reduction or deterioration of the biological or economic efficiency and impacts of rainfed, irrigated, or grassland, forest, and irrigated land caused by land use or development, or the combination of developments. This includes processes caused by actions such as soil erosion; the decline in physical, chemical, biological, or economic assets of the soil; and the permanent loss of natural vegetation [3].

The main challenge facing patchouli cultivation in Aceh Tamiang Regency is limited information on soil quality. Therefore, one effort to increase land productivity should focus on improving land quality. This approach is expected to increase the competitiveness of patchouli cultivation and support the long-term aspirations of the patchouli cultivation sector in Aceh Tamiang Regency.

Most of the methodologies currently used to characterize soil fertility in production and its suitability for various uses date back several decades. These measurements have been complemented by techniques using sensors and various data analysis software that allow us to manage more and better information [4]. One new and applicable method for conducting soil quality tests is the Visual Evaluation of Soil Structure (VESS) method. This method requires simple soil assessment requirements and provides a morphological description of the soil structure based on visual observation of the soil profile. The results are easy to process and understand [5]. Visual assessment provides a direct diagnostic tool for assessing soil quality, as many physical, biological (and, to a lesser extent, chemical) soil characteristics appear as visual features [6]. The VESS method was developed to help land managers assess soil quality easily, quickly, reliably, and economically in agricultural systems [7].

Based on the aforementioned issues, it is clear that land degradation is a significant problem in patchouli cultivation in Aceh Tamiang Regency due to its negative impacts on crop production and the environment. To address this problem, alternative land management systems are needed that aim to maintain or even improve soil quality. The aim of this study was to determine the soil fertility status at patchouli planting locations and to determine soil quality using the VESS method.

## 2. Research Methods

*2.1 Study site and research period*

This research was conducted in Sekerak District, Aceh Tamiang Regency (Figure 1). The study period was four months, from May to August 2025.

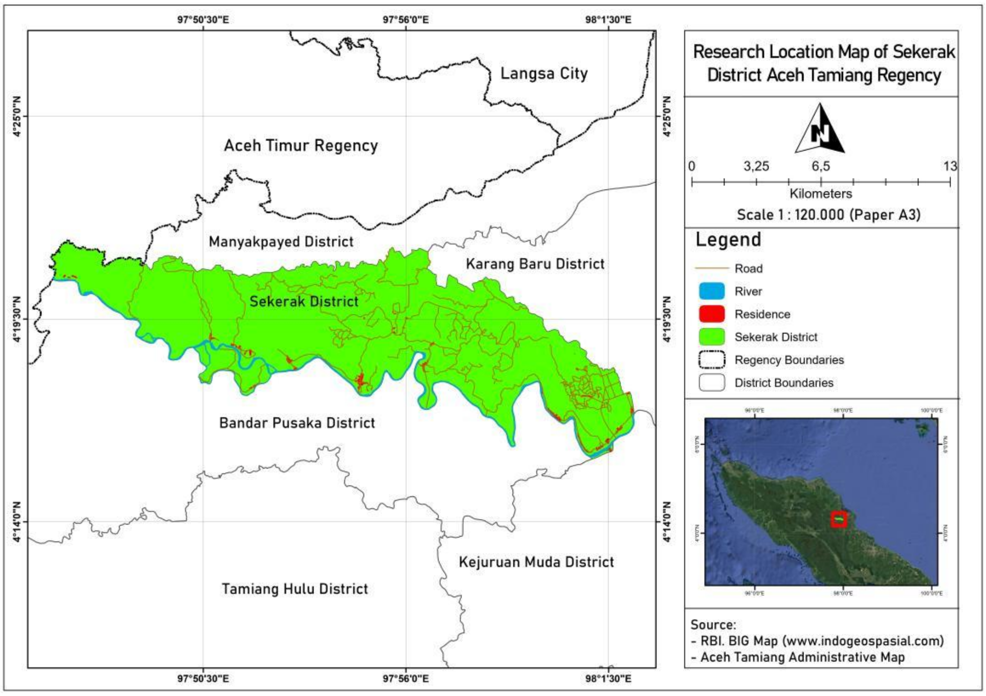


**Figure 1.** Research location.

*2.2 Methods*

*Soil Sampling*

Soil sampling was conducted at seven patchouli cultivation sites in four villages in Sekerak District, Aceh Tamiang Regency, using three planting methods: mixed gardens (sites 1-3), intercropping (sites 4-6), and monoculture (site 7). (Figure 2).

Disturbed soil samples were collected using purposive sampling from 20 m x 20 m experimental quadrants. Samples were collected with a hoe at four points in each study site. The soil samples were then composited, placed in plastic bags, and labeled. Undisturbed soil samples were collected using a ring sampler, taken at the same points as the disturbed soil samples. The observed soil properties are shown in Table 1.

*Soil Sampling (VESS Method)*

This simple and rapid test assesses soil structure based on the appearance of lumps of soil excavated with a hoe. Soil sampling was conducted while the soil was moist.

Each study site was divided into four equal plots, with one sampling point per plot randomly selected. Undisturbed samples (blocks) were then taken from mini-trenches (0.15 x 0.25 x 0.10 m) using a straight shovel. A total of 28 samples were taken from patchouli cultivation areas (7 study sites, 4 samples per site, and 1 topsoil layer at a depth of 0-20 cm).

**Table 1.** Soil properties analyzed in the laboratory.

| No | Parameter | Unit | Analysis method |
|---|---|---|---|
| | Soil physics | | |
| 1 | *Bulk density* | $gr/cm^3$ | Gravimeterik |
| 2 | Porosity | % | Piknometer |
| 3 | Soil texstur | % | Hidrometer |
| | Soil chemical | | Gravimeterik |
| 1 | pH | - | Elektrometric |
| 2 | C-Organic | % | Walky & Black |
| 3 | N-Total | % | Kjedahl |
| 4 | P-Total | % | Extraction of 25% HCL |
| 5 | K-Total | % | Extraction with HCL 25% |
| 6 | Base saturation | % | Calculated based on the number of bases divided by CEC multiplied by 100 |
| 7 | CEC | Me/100 gr | Extraction with NH4OaC pH 7 |

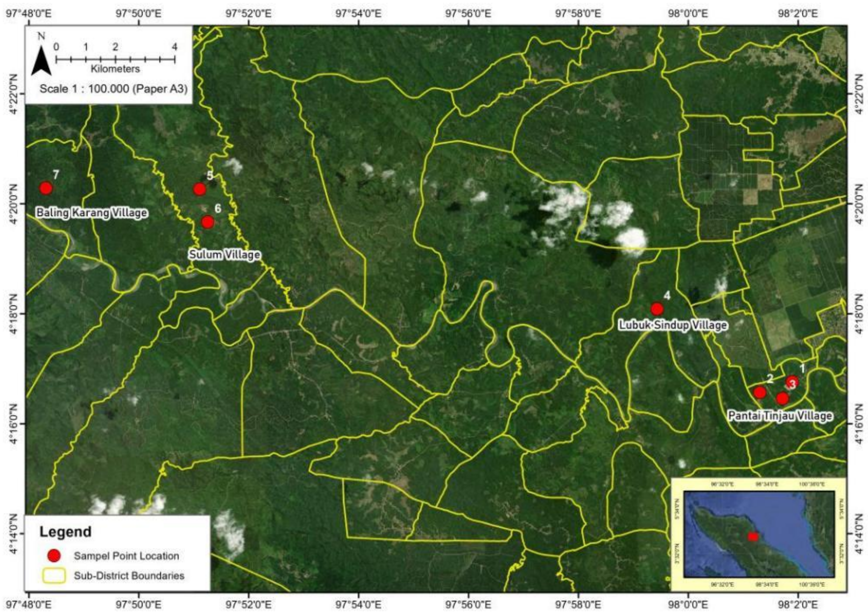


**Figure 2.** Soil sampling location.

*2.3 Data analysis*

*Soil fertility status*

The technical guidelines for soil fertility evaluation issued by the Bogor Soil Research Center are used to determine the criteria for soil chemical properties and soil fertility status at patchouli cultivation locations [8].

*VESS Scoring Analysis*

Soil sample slices were broken by hand along natural aggregate fracture lines to determine soil structure. Soil was then collected from the 0-20 cm layer, resulting in a total of 28 samples (7 research locations × 4 points per location). The soil was visually evaluated according to the methodology, comparing the appearance of the soil aggregates after manual crushing [9].

This methodology states that after the soil slices are extracted, the aggregates are classified along the fracture lines and their structure is scored. Aggregates are evaluated according to size, resilience, color, visible porosity, and shape. Scores range from 1 (good structural quality) to 5 (poor structural quality). The final score is determined and calculated using a weighted average (Table 2).

**Table 2.** Soil quality score classification.

| VESS Value | Soil Structure Quality | Land Management Improvement |
|---|---|---|
| 1 - 2 | Good | No land management required |
| 2,1 - 3 | Medium | Short-term improvements required |
| 3,1 - 5 | Low | Long-term improvements required |

Source : [9]

The collected soil samples are scored using the following scoring formula:

$$\text{Sqscore} = \sum \frac{SqiTi}{TT} \qquad (1)$$

Where:

| | | |
|---|---|---|
| Sqscore | = | Overall VESS Value |
| Sqi | = | VESS value at the ith thickness |
| Ti | = | Thickness of the ith soil sample |
| TT | = | The total thickness of the entire soil |

Source : [9].

## 3. Results and Discussion

*3.1 Soil chemicals properties*

The results of the analysis of soil chemical properties at all research locations are presented in Table 3.

**Table 3.** Results of analysis of soil chemical properties.

| Sample location | Parameter | | | | | |
|---|---|---|---|---|---|---|
| | C-organic (%) | P-Total (mg/100g) | K-total (mg/100 g) | CEC (mg/100 g) | Base Saturation (%) | pH |
| 1 | 1,32 (L) | 0,05 (VL) | 0,17 (VL) | 17,25 (M) | 33,06 (L) | 4,96 (A) |
| 2 | 0,88 (VL) | 0,04 (VL) | 0,17 (VL) | 12,45 (L) | 28,03 (L) | 4,71 (A) |
| 3 | 0,77 (VL) | 0,03 (VL) | 0,15 (VL) | 17,65 (M) | 29,59 (L) | 4,76 (A) |
| 4 | 0,83 (VL) | 0,03 (VL) | 0,11 (VL) | 10,45 (L) | 27,56 (L) | 4,37 (A) |
| 5 | 0,64 (VL) | 0,03 (VL) | 0,12 (VL) | 10,10 (L) | 30,27 (L) | 4,57 (A) |
| 6 | 0,74 (VL) | 0,03 (VL) | 0,10 (VL) | 10,50 (L) | 25,03 (VL) | 4,36 (A) |
| 7 | 0,44 (L) | 0,02 (VL) | 0,07 (VL) | 9,70 (L) | 17,62 (VL) | 4,26 (A) |

Letters inside the brackets indicate soil properties status: VL: Very Low, L: Low, M: Medium, H: High, VH: Very High, VA: Very Acid, A= Acid.

Table 3 above shows the results of the analysis of several soil chemical properties. In general, the results of the analysis of soil chemical properties at all sample locations were classified as very low. Total P was classified as very low (0.02-0.05 mg/100g), total K was classified as very low (0.07-0.17 mg/100g), organic C content was classified as very low to low (0.44-1.32%), CEC content was classified as low to moderate (9.70-17.25%), base saturation was classified as very low to low (17.62-33.06%), and the soil was classified as acidic (pH 4.26-4.96).

The range of soil chemical properties most suitable for patchouli growth includes pH (5.5-7), organic carbon content (2-7%), total phosphorus content (16-25 mg/100 g), total potassium content (>1 mg/100 g), and CEC content (>17%) [10]. The main limiting factor contributing to the poor soil chemical properties at the research site was the acidic soil pH. Acidic soil conditions cause easy fixation of phosphorus and potassium, low absorption and utilization of media and micronutrients, and weak root growth, resulting in increased fertilizer use but poor plant growth [11].

Soil acidity not only causes essential nutrient deficiencies but also contributes to the accumulation of harmful substances, such as exchangeable aluminum ($Al^{3+}$), in the soil [12]. Furthermore, soil acidification can reduce the soil's capacity to retain N, P, K, and other essential nutrients [13].

*3.2 Soil fertility status*

The results of the soil fertility status assessment are presented in Table 4.

**Table 4.** Assessment of soil fertility status.

| Sample location | CEC | Base saturation | P-Total | K-total | C-organic | Soil fertility status |
|---|---|---|---|---|---|---|
| 1 | M | L | VL | VL | VL | L |
| 2 | L | VL | VL | VL | VL | L |
| 3 | M | VL | VL | VL | VL | L |
| 4 | L | L | VL | VL | VL | L |
| 5 | L | L | VL | VL | VL | L |
| 6 | L | L | VL | VL | L | L |
| 7 | L | L | VL | VL | L | L |

Notes: VH = Very High, H = High, M = Medium, L = Low, VL = Very Low

Table 4 shows the results of the soil fertility assessment at all patchouli cultivation sites in the study area, where all locations had low soil fertility. This is thought to be due to low organic C, total P, and total K values, which are limiting factors, resulting in low soil fertility. These data underscore the need to implement a comprehensive and balanced fertilization program in Patchouli fields at the research site to increase crop production. The N, P, and K nutrient requirements for patchouli plants are 500 kg of urea + 250 kg of SP-36 + 450 kg of KCl, applied five times for four harvests, or 100 kg of urea + 50 kg of SP-36 + 90 kg of KCl for one harvest or one planting period [10].

To reduce the potential for Al poisoning in acidic soil pH, efforts must be made to increase soil pH by applying soil amendments such as biochar and manure as well as applying dolomite lime. Efforts to improve soil fertility can be done by applying dolomitic lime. Dolomitic lime can raise soil pH, allowing potential phosphorus to become available to plants, while also exchanging K+ ions trapped in clay for Ca and Mg from the lime.

In the long term, increases in productivity induced by liming, result in increasing soil pH, available phosphorus, cation exchange capacity, basic cations, microbial activity, organic carbon, total nitrogen, and decreasing leaching of nutrients, exchangeable aluminum, and acidity, all favoring the physical and chemical properties of the soil [14].

In order for patchouli cultivation carried out by farmers at the research location to continue in the future, the concept of sustainable patchouli cultivation intensification combined with the management of the Agro-Pedoecology Unit can be implemented. In patchouli cultivation, to prevent soil fertility degradation, it is recommended to use non-synthetic fertilizers in optimal doses combined with synthetic fertilizers based on the 5 T principle (right type, right dose, right time, right method, and right target) [15].

*3.3 Soil quality scores*

The results of the DMRT test on soil quality values at several patchouli cultivation locations at the research location can be seen in Table 5.

**Table 5.** DMRT results for soil quality scores.

| Sample location | VESS score |
|---|---|
| 1 | 1,67 d |
| 2 | 1,83 c |
| 3 | 1,85 c |
| 4 | 1,86 c |
| 5 | 1,99 b |
| 6 | 1,98 b |
| 7 | 2,13 a |

Note: Numbers followed by different letters in the same column are significantly different at a 95% confidence interval (P-value) < 0.05.

Table 5 shows differences in soil quality across each patchouli cultivation system. The VESS values across all study sites ranged from 1.67 to 2.13. Of the seven sample points, only sample site 7 had a VESS value above 2, which is classified as moderate and requires improved land management to improve soil quality.

Further test results indicate significant differences in VESS values across each sample site. Sample sites 1-6 (mixed garden and intercropping patchouli cultivation systems) had good soil quality. Conversely, sample site 7 (monoculture patchouli cultivation system) had moderate soil quality.

Good soil quality values indicate that the soil in patchouli cultivation sites using mixed garden and intercropping systems has better soil fertility, characteristics, and physical properties (texture, bulk density, and porosity) than those in monoculture systems. Furthermore, extensive tillage with conventional fertilizers and the absence of trees have led to soil compaction in monoculture patchouli cultivation areas. Land degradation will occur if monoculture patchouli cultivation systems continue. The mixed patchouli cultivation system, which uses organic matter to reduce soil compaction, is a key technique for improving soil structure.

Medium soil quality in monoculture patchouli cultivation systems is limited by poor soil porosity, acidic pH, low organic carbon content, and very low P and K levels. These factors create a less than optimal environment for patchouli growth [16]. Efforts to improve soil quality in patchouli cultivation areas include the addition of ameliorants, particularly organic materials such as compost, biochar, and manure [17].

## 4. Conclusions

The patchouli cultivation land at the research location has acidic soil pH, low CEC and base saturation, and very low total P, total K and organic C. Based on these parameters, the soil fertility status at the research location is categorized as low. The soil quality values were classified as good at 6 sample locations that practiced mixed and intercropping patchouli cultivation systems.

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