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Evaluating land suitability for kemiri (*Aleurites moluccana*) as a multi-purpose tree species in community agroforestry land within Langkat District, North Sumatra

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ABSTRACT

Evaluating land suitability for *Aleurites moluccana* in community agroforestry land within Langkat District, North Sumatra, is crucial for promoting sustainable development, enhancing livelihoods, and preserving ecosystems while honoring local traditions and cultures. The primary objective of this research was to evaluate and map the land suitability for *A. moluccana* within Langkat District, located in North Sumatra, Indonesia. To gather the necessary data, this study employed a survey method, involving the collection of soil samples from ten distinct land units within the field. The assessment of land suitability was carried out using the matching method. Geographic Information System (GIS) technology was utilized to create maps illustrating the distribution of land suitability, while a Global Positioning System (GPS) was employed to accurately record the coordinates of the collected soil samples. The findings revealed that within Gunung Ambat, Simpang Kuta Buluh, Rumah Galuh, and Telagah Village, the actual land suitability classes for *A. moluccana* were classified as moderately suitable (S2) and marginally suitable (S3). The prevailing limiting factors in this region were temperature (tc) and the characteristics of the root zone medium (rc). Consequently, this influenced the potential land suitability classes for *A. moluccana*, resulting in classifications ranging from highly suitable (S1) to moderately suitable (S2) and marginally suitable (S3). By implementing land suitability evaluation for *A. moluccana* in community agroforestry land, promoting sustainable land use, enhancing livelihoods, and conserving natural resources.

Keyword: GPS, Land, Land Unit, Soil, Suiability

1. Introduction

Land assessment is the process of evaluating a piece of land's potential for specific purposes. Land suitability, on the other hand, refers to how well a particular piece of land aligns with specific intended uses [1]-[4]. The results of land assessment serve as a foundation for informed and sustainable land use planning, ensuring that land is utilized optimally [5]. Land suitability assessments are essential as they guide decision-making related to land use [6]. Land suitability assessments play a crucial role in guiding decision-making related to land use by providing objective, scientific information about the suitability of land for specific purposes. They help in

promoting sustainable development, reducing risks, and maximizing the benefits of land resources for both present and future generations [6]-[8]. The land evaluation process entails comparing the requirements of the intended land use with the characteristics of the land in question. Land suitability is typically categorized into two classes: actual land suitability and potential land suitability [2], [7]-[8]. Actual land suitability reflects the land's suitability in its natural state without considering potential improvements or management practices to address limiting factors. These limiting factors can be classified into two types: permanent (which cannot be feasibly rectified) and those that can be improved, often economically, through the adoption of appropriate technologies, for example.

The results of land evaluation can be effectively represented in the form of maps through the utilization of Geographic Information System (GIS) technology. Numerous research endeavors have demonstrated the utility of GIS for converting vegetation data collected from on-ground surveys into comprehensive maps and analytical insights. For instance, GIS techniques have been successfully employed to map potential areas for rubber plantation in India [9]. In the realms of forestry and agriculture, GIS has emerged as a valuable tool with numerous applications. One particularly noteworthy use of GIS technology is in the mapping and visualization of land evaluation results [10]-[23]. Through GIS, land evaluators can efficiently display and share this information with stakeholders, land managers, and decision-makers. GIS allows for sophisticated spatial analysis, which goes beyond traditional maps. It can help identify patterns, trends, and relationships within land evaluation data. For example, GIS can reveal clusters of highly suitable areas for a particular crop or forest species, helping planners make informed decisions about land allocation and resource management.

GIS facilitates the integration of various data layers, such as soil types, topography, climate data, and land use history. By combining these diverse datasets, land evaluators can generate comprehensive suitability assessments that take into account multiple factors influencing land use decisions [17], [19]. GIS offers the capability to simulate different scenarios and their potential impacts on land suitability. Planners can use GIS to assess how changes in climate, land management practices, or land cover might affect future suitability for agriculture or forestry. This allows for proactive planning and adaptation to changing conditions. GIS provides decision support tools that help stakeholders make informed choices about land use and resource allocation [20], [22]. By visualizing land suitability data in an accessible and interactive format, decision-makers can weigh the pros and cons of different land use options and select the most suitable course of action. GIS assists in optimizing resource allocation by identifying areas with high land suitability, which can lead to increased agricultural yields, improved forest management, and more efficient land use practices. This optimization can have significant economic and environmental benefits. GIS has become an indispensable tool in the fields of forestry and agriculture due to its ability to map, analyze, and visualize land evaluation outcomes. It supports data-driven decision-making, spatial analysis, and resource optimization, contributing to more sustainable and efficient land use practices. Its versatility and applicability across various domains make GIS a valuable asset in land management and planning processes [17]-[23].

In Langkat District, the local community has planted *A. moluccana* on agroforestry land as part of their Multi-Purpose Tree Species (MPTS) initiatives. Kemiri provide many benefits and opportunities for farmers and society. However, a major challenge faced by these community plantations is low productivity. To overcome the challenges related to kemiri cultivation, an integrated approach is needed that considers agronomic, economic and environmental factors. Given the substantial potential for kemiri development in this area, addressing these productivity issues requires careful planning. It is imperative to ensure that kemiri is cultivated in locations that meet specific criteria related to plant growth (biophysics), spatial considerations, and economic aspects. Therefore, providing guidance to the community in selecting optimal cultivation sites becomes essential. The proper selection of these sites will result in maximum productivity and, in turn, lead to greater benefits for the community. Surprisingly, there has been no prior research conducted to map the suitability of the land for kemiri in this particular area. Given this context, it becomes crucial to assess and map the actual as well as potential land suitability classes for kemiri in North Sumatra Province. Hence, the primary aim of this study is to evaluate the viability of developing smallholder *A. moluccana* plantations in North Sumatra Province, with a specific focus on the physical aspects within Sei Bingai Sub-District, Langkat District. The outcomes of this research endeavor are anticipated to serve as valuable input for the formulation of policies by local governments pertaining to the development of smallholder *A. moluccana* plantations in North Sumatra Province, particularly within the confines of Langkat District in North Sumatra Province.

2. Method

The study was carried out in Gunung Ambat, Simpang Kuta Buluh, Rumah Galuh, and Telaga Village, which are situated within Sei Bingai Sub-District, Langkat District, North Sumatra Province, as indicated in Figure 1. The research took place in Gunung Ambat, Simpang Kuta Buluh, Rumah Galuh, and Telaga Village due to the prevalent presence of agroforestry systems in these areas. By conducting the study in those villages, researchers can gain insights into the potential opportunities and challenges of integrating kemiri cultivation into existing agroforestry systems, contributing to sustainable rural development and natural resource management in the region.

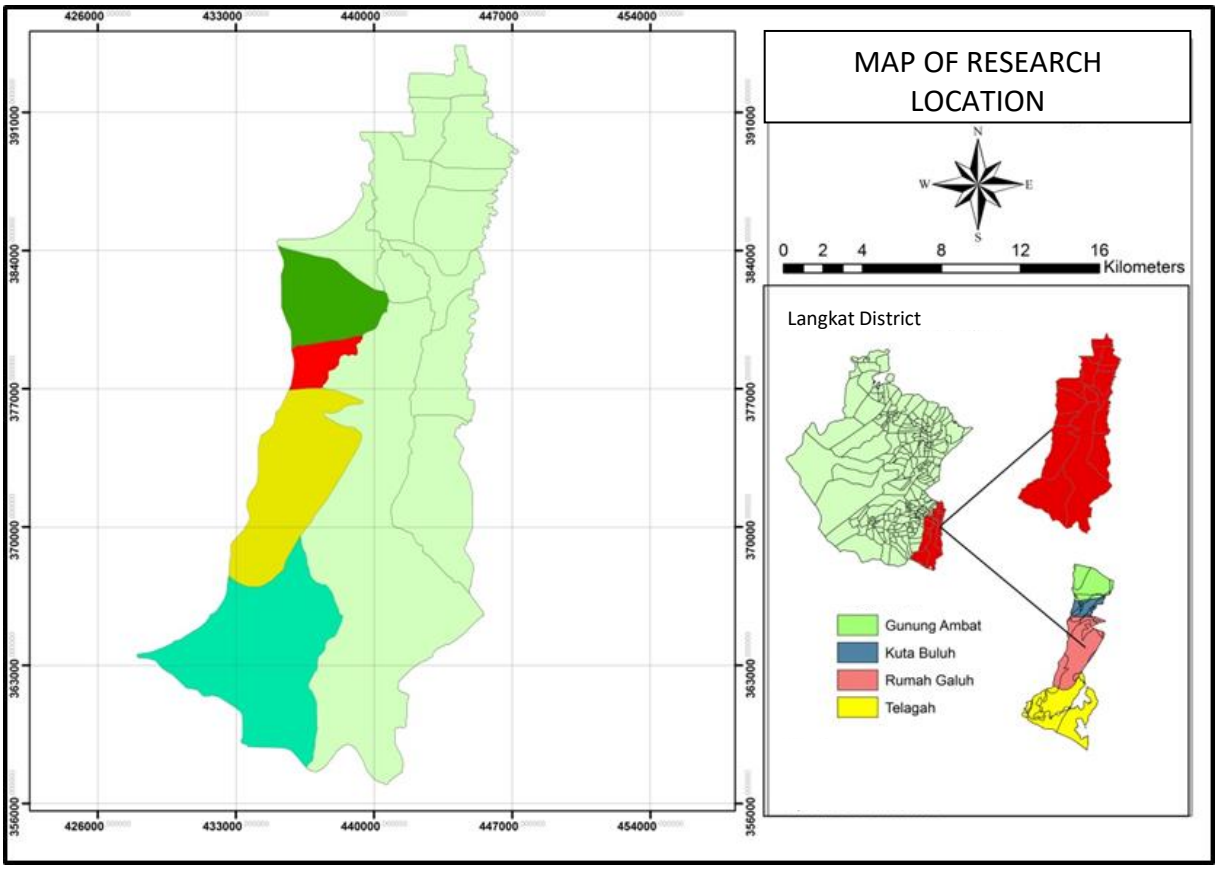

Figure 1. Map of Research Location

The survey method was employed to gather soil samples directly from the field. The classification of land suitability (LSC) was determined using the matching method [6]. Reference values and criteria were adopted from the "Land Suitability for Agricultural Plants" provided by the Centre for Soil and Agroclimate Research in Bogor, Indonesia [5],[24]. Several land qualities and characteristics were taken into account, including temperature (tc), water availability (wa) (annual rainfall), oxygen availability (oa) (drainage), root zone medium (rc) (texture, soil depth), nutrient retention (nr) (cation exchange capacity, base saturation, pH, organic carbon content), sodicity (alkalinity), erosion hazard (eh) (slope, soil erosion), and flood hazard (fh) (inundation). Geographic Information System (GIS) technology was utilized to create maps illustrating the different land suitability classes, both actual and potential.

The results of the land suitability assessment for *A. moluccana*, encompassing both the actual and potential suitability classes, were effectively communicated through a combination of tables and maps. These presentation formats offered detailed descriptions of the suitability classes, which were categorized into four main classes: Highly suitable (S1), Moderately suitable (S2), marginally suitable (S3), and not suitable (N). The deeper understanding of these categories and how they were determined:

2.1. Highly Suitable (S1)

This classification designates areas that are exceptionally well-suited for the cultivation of *A. moluccana*. Land units falling into this category provide ideal conditions for the tree's growth, leading to high productivity

and minimal constraints. These areas are typically characterized by favorable soil properties, climate conditions, and terrain features that support robust plant development.

2.2. Moderately Suitable (S2)

Land units classified as moderately suitable are characterized by conditions that are favorable for *A. moluccana* growth but may have some limitations or constraints. While they offer good potential for cultivation, there might be factors, such as soil properties or climatic variations, that can moderately affect productivity. Nonetheless, with proper management, these areas can still yield satisfactory results.

2.3. Marginally Suitable (S3)

This category includes land units with limitations that make them marginally suitable for *A. moluccana* cultivation. While growth is possible, these areas have significant constraints that may reduce productivity, increase resource requirements, or pose challenges for successful cultivation. Addressing these limitations may necessitate additional investments or interventions.

2.4. Not Suitable (N)

Land units falling into this category are deemed unsuitable for *A. moluccana* cultivation. They possess inherent limitations or constraints that are severe enough to render cultivation of this tree species unfeasible or impractical. These limitations may include extreme soil properties, unfavorable climate conditions, or other factors that make *A. moluccana* growth highly unlikely.

The categorization of suitability classes is based on established criteria and guidelines, often derived from previous research and expert knowledge [7],[10]. These classes help stakeholders, land planners, and decision-makers quickly assess the potential of different land units for *A. moluccana* cultivation. By providing a clear and standardized classification system, this approach aids in informed decision-making regarding land allocation, resource management, and land use planning.

Data collection involved obtaining primary data through field surveys and soil sample analyses conducted in a laboratory setting. Soil sampling was carried out in each village in a representative manner based on land units (ten land units) so that it could represent the area being evaluated comprehensively. Based on the land unit, 31 soil samples were taken which were then analyzed in the laboratory. Secondary data was sourced from existing literature and various institutions, including climatology stations and the Ministry of Forestry. The process of land suitability evaluation entailed a comparison of land characteristics with the specified requirements for the growth of *A. moluccana*, as outlined in the Technical Guidelines for the evaluation of land for agricultural commodities [24]. This evaluation process involved the following steps: (1) preparation of land characteristic data, (2) compilation of plant growth requirements, and (3) assessing land suitability by matching land characteristics with the criteria for crop cultivation, resulting in the determination of land suitability classes (Figure 2). The assessment of land suitability classes was conducted using the matching method [17]-[23]. Actual land suitability represents the suitability classes based on survey data obtained directly from the research area without any modifications or improvements considered. In contrast, potential land suitability reflects the land's suitability after any necessary improvement efforts have been implemented.

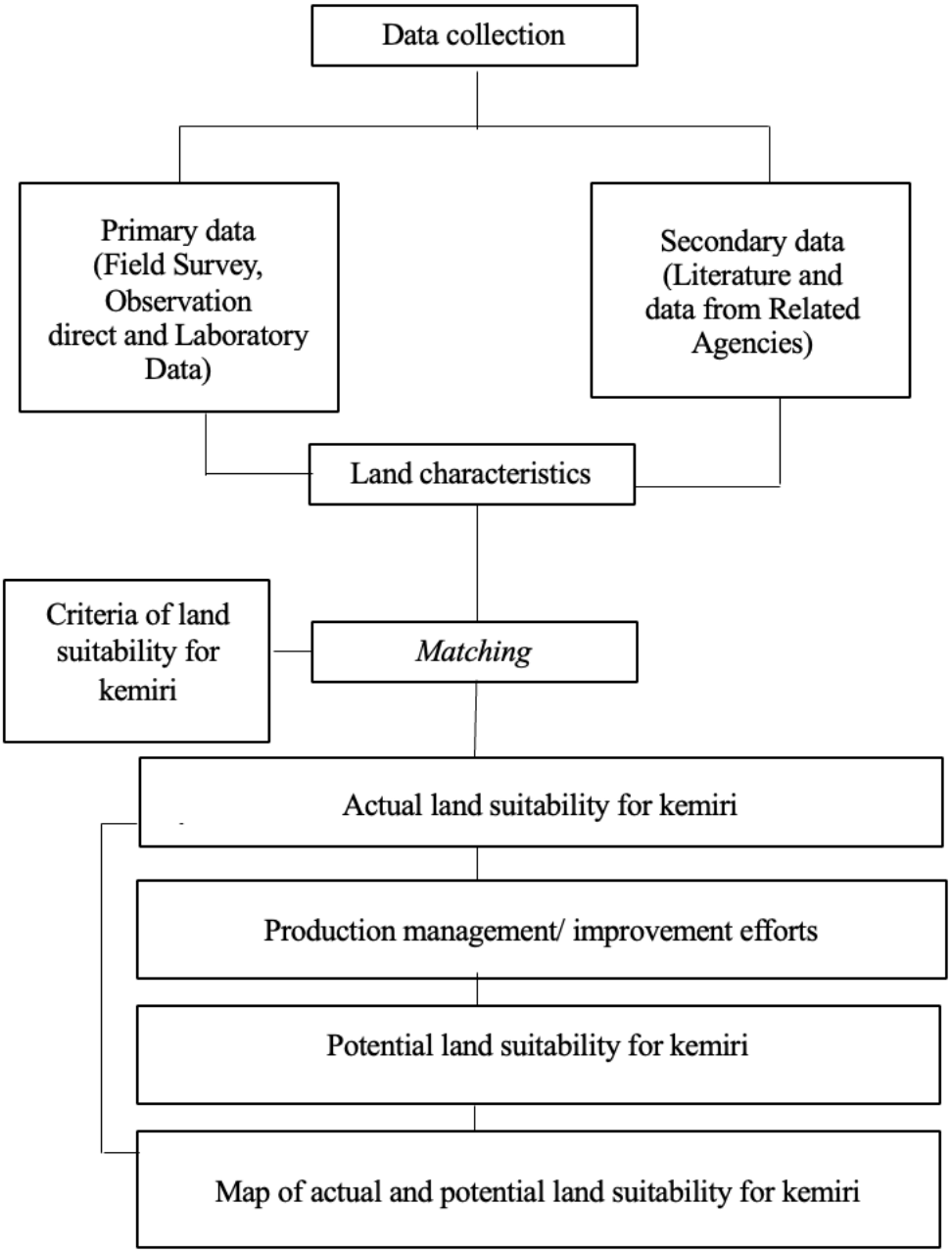

Figure 2. Evaluation process scheme

3. Results and Discussion

The study's findings revealed that within Gunung Ambat, Simpang Kuta Buluh, Rumah Galuh, and Telagah Village (Table 1), the actual land suitability classes for *A. moluccana* were distributed as follows: Land Unit 1, 4, 5, 6, 7, and 9 were categorized as moderately suitable (S2), constituting 88.94% of the region. Meanwhile, Land Unit 2, 3, 8, and 10 were classified as marginally suitable (S3), accounting for 11.06% of the entire area. These classifications primarily influenced by the dominant limiting factors in the area, which encompassed temperature (tc) and the characteristics of the root zone medium (rc). Consequently, these factors played a significant role in determining the suitability of the land for *A. moluccana*.

Table 1. Illustrates the present land suitability classes for *A. moluccana* in Langkat District

Land Unit	Actual land suitability	Area	
		Ha	(%)
1	S2 eh	2,422.70	21.51
2	S3 rc	836.65	7.43
3	S3 rc,eh	307.84	2.73
4	S2 tc,rc,eh	986.62	8.756
5	S2 tc,rc,eh	514.01	4.56
6	S2 tc	571.88	5.07
7	S2 tc,rc,eh	1,152.67	10.23
8	S3 eh	11.19	0.10
9	S2 tc,rc,eh	4,372.35	38.82
10	S3 rc	89.33	0.80
Total		11,265.29	100

Note: S2: Moderately suitable, S3: Marginally suitable; tc: temperature, rc: root zone medium, eh: erosion hazard

Referring to Table 2, an analysis of the potential land suitability classes for *A. moluccana* reveals the following classifications: Highly Suitable (S1) was found in Land Unit 1, constituting 21.51% of the total area. This designation indicates that the land in this unit is highly suitable for *A. moluccana* cultivation. Moderately suitable (S2) was observed in Land Unit 4, 5, 6, 7, 8, and 9, encompassing a substantial 67.44% of the region. This classification signifies that these land units offer favorable conditions for *A. moluccana* growth, albeit with some limitations. Marginally suitable (S3) was identified in Land Unit 2, 3, and 10, representing 10.96% of the land area. Land falling under this category has limitations that make it less suitable for *A. moluccana* cultivation. It's important to note that in this region, the primary factors constraining land suitability continue to be temperature (tc) and the characteristics of the root zone medium (rc). These factors play a pivotal role in determining the suitability of the land for successful *A. moluccana* cultivation and are key considerations for land use planning in this area. It is crucial to emphasize that the most formidable challenges encountered in this study were related to the root zone medium (rc) and temperature (tc), primarily because these limitations were intrinsic to the natural conditions of the region [3],[7].

Table 2 presents the potential land suitability classes for *A. moluccana*

Land Unit	Potential Land Suitability	Area	
		Ha	(%)
1	S1	2,422.70	21.51
2	S3,rc	836.65	7.43
3	S3,rc	307.84	2.73
4	S2,tc,rc	986.62	8.76
5	S2,tc,rc	514.01	4.56
6	S2,tc	571.88	5.07
7	S2,tc,rc	1,152.67	10.23
8	S2,tc,rc	11.19	0.10
9	S2,tc,rc	4,372.35	38.82
10	S3,rc	89.33	0.80
	Total	11,265.29	100

Note: S1: Highly Suitable, S2: Moderately suitable, S3: Marginally suitable; tc: temperature, rc: root zone medium

Root Zone Medium (rc): This refers to the properties of the soil, including its texture and depth, which influence the ability of plants like *A. moluccana* to establish a robust root system and access essential nutrients and water. In the study area, the root zone medium posed a significant challenge. Soils may have been unsuitable in terms of texture, depth, or nutrient content, which can hinder the growth and development of *A. moluccana*. Addressing this limitation often involves soil improvement measures, which can be costly and require substantial efforts [20],[23]. Temperature (tc): Temperature plays a critical role in determining the success of *A. moluccana* cultivation. This factor encompasses the average temperature range experienced in the area. In cases where temperature conditions are not within the optimal range for the species (20 - 27°C in this context), it can adversely affect the growth and productivity of *A. moluccana*. Managing temperature limitations often involves selecting suitable planting sites or implementing climate control measures, both of which can be challenging and resource-intensive [17]-[23].

In cases where the land is categorized as Class S3, it implies that the land possesses limitations severe enough to significantly reduce the productivity and benefits derived from *A. moluccana* cultivation. These limitations may necessitate increased inputs, such as additional resources, labor, or technology, to mitigate the adverse effects on plant growth [17]-[23]. The expenditure required to overcome these constraints may be only marginally justifiable, meaning that the costs of cultivation may outweigh the potential benefits, making it a less attractive option for farmers or land managers. The study highlighted that the root zone medium and temperature were fundamental factors affecting the suitability of the land for *A. moluccana* cultivation. Class S3 indicated that the land had substantial limitations, potentially requiring substantial investments and efforts to make it suitable for productive cultivation, and these factors should be carefully considered in land use planning and decision-making.

The slope (eh) could potentially be improved through terracing steep areas. However, addressing the limiting factors within S3 would demand substantial capital investment, potentially necessitating government or company assistance or intervention. The comparison between the actual and potential land suitability classes for *A. moluccana* is visually depicted in Figure 3 and Figure 4.

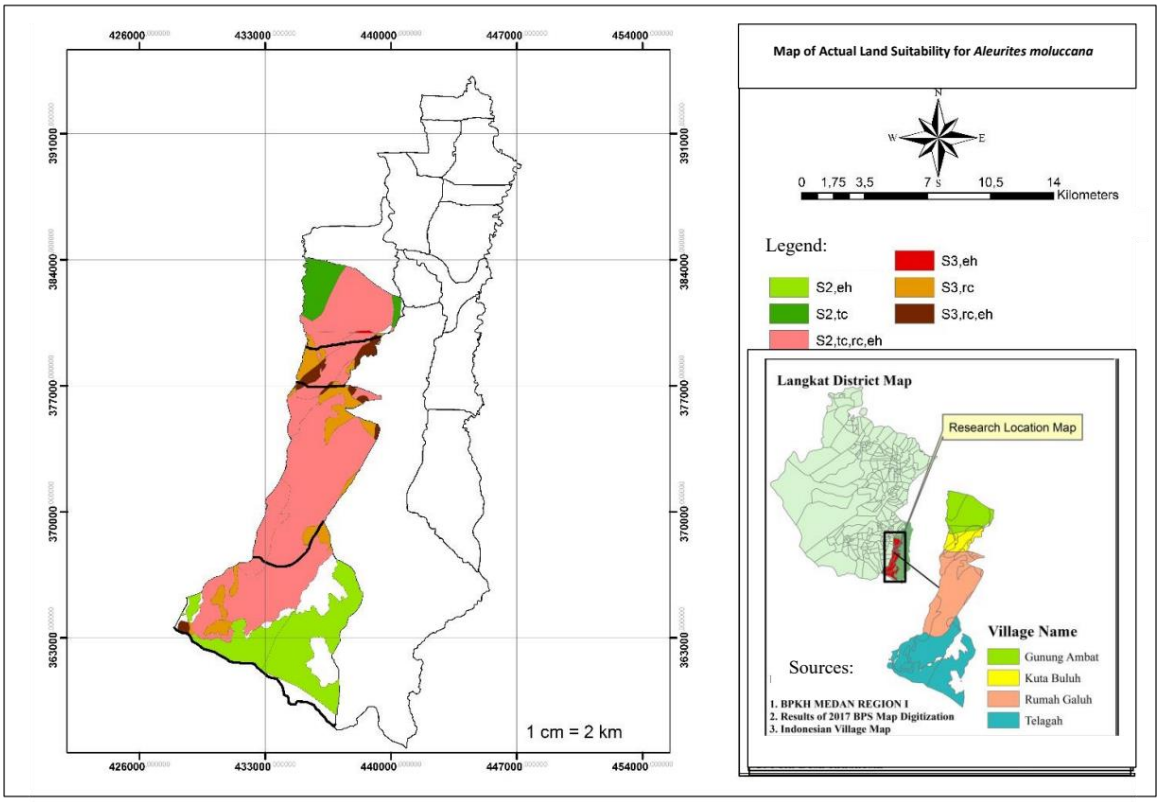

Figure 3. displays the map illustrating the spatial distribution of the actual land suitability for *A. moluccana* in Langkat District

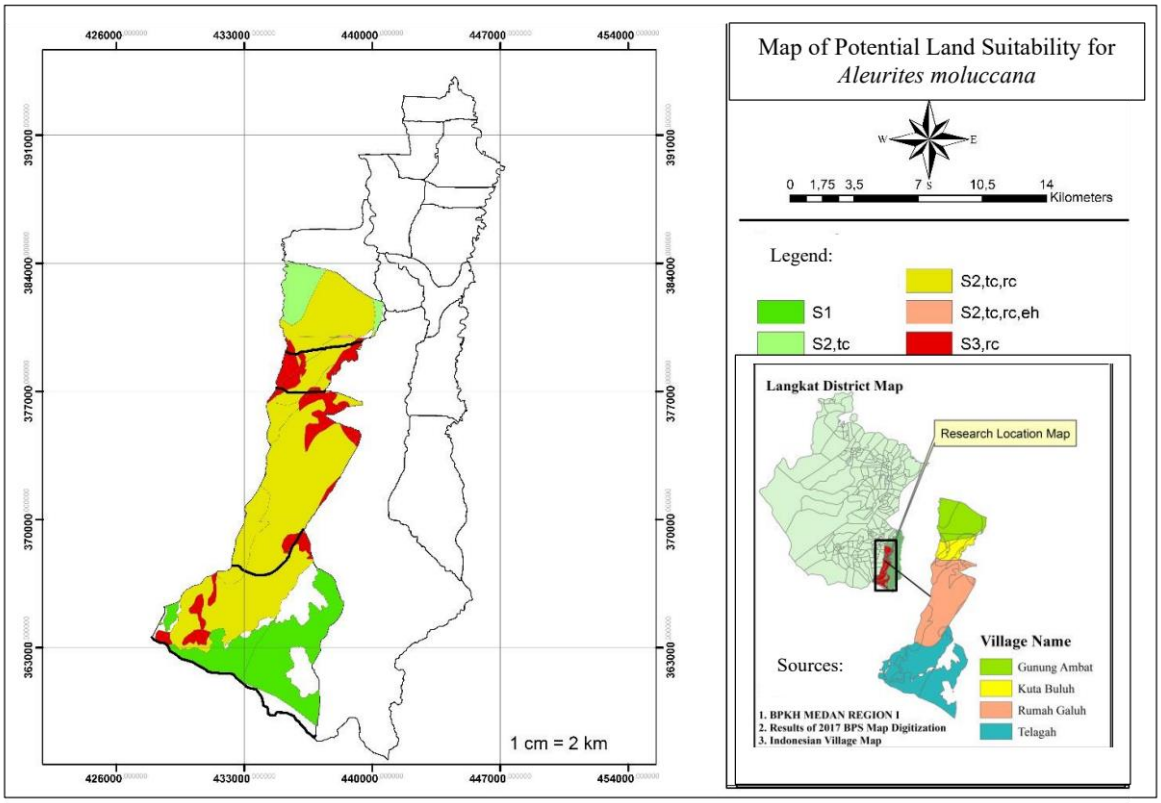

Figure 4. presents a map depicting the distribution of the potential land suitability for *A. moluccana* within Langkat District

In order to achieve optimal growth, *A. moluccana*, commonly known as Kemiri, requires specific land suitability conditions that are essential for its successful development. These conditions are particularly critical because they directly impact the tree's ability to thrive and produce a bountiful harvest. Here's a more detailed explanation of these suitability conditions. *A. moluccana* thrives on limestone-rich soils. Limestone is a type of sedimentary rock composed primarily of calcium carbonate. Soils derived from limestone are typically well-draining, have a balanced pH level, and offer good aeration [23]. These characteristics are advantageous for *A. moluccana* because they allow for proper root development, efficient nutrient uptake, and a reduced risk of waterlogging, which can be detrimental to the tree's health. Another suitable soil type for *A. moluccana* cultivation is sandy beachside soils. Sandy soils are well-known for their excellent drainage properties, which prevent water from accumulating around the roots and causing root rot. They also tend to warm up quickly in the sun, providing a favorable environment for the tree, especially in regions where temperature is a critical factor. Additionally, sandy soils are relatively easy to work with and allow for good root penetration and expansion [23].

A. moluccana grows best at altitudes ranging from sea level up to 800 meters above sea level. This elevation range provides the right combination of temperature, humidity, and climatic conditions for its growth. The tree thrives in areas with annual rainfall between 1,500 and 2,400 mm, which ensures an adequate water supply for its needs. It also prefers temperatures within the range of 20 to 27°C, as these temperatures are conducive to healthy growth and fruit production [20],[24]. *A. moluccana* has specific requirements when it comes to the type of soil it grows in, with limestone-rich and sandy beachside soils being particularly suitable. Moreover, the tree's altitude and climate preferences ensure that it can thrive and produce optimal yields. Understanding and providing these suitable conditions are crucial for successful cultivation and maximizing the benefits of *A. moluccana* cultivation. *A. moluccana*, commonly known as Kemiri, demonstrates robust growth and productivity under specific environmental conditions. Let's delve into a more detailed explanation of these conditions. *A. moluccana* thrives within an elevation range from sea level to 800 meters above sea level. This wide altitudinal tolerance makes it adaptable to various terrains and elevations. Whether it's cultivated on flatlands, gently sloping hills, undulating surfaces, or even steep cliffs, the tree can successfully establish and grow. This adaptability to diverse terrains is advantageous for farmers and land managers, as it allows for flexibility in choosing suitable planting locations. Adequate rainfall is essential for the growth and health of *A. moluccana*. The tree flourishes in regions with annual rainfall levels ranging from 1,500 to 2,400

millimeters. This rainfall range ensures a consistent and sufficient water supply throughout the year, promoting healthy growth and fruit production [23]. Adequate moisture availability is particularly critical during the tree's growing season, as it supports the development of leaves, flowers, and fruits.

Temperature range (20° - 27°C) [24], means that temperature plays a pivotal role in the growth of *A. moluccana*. The tree's preferred temperature range falls between 20 and 27°C. Within this range, the tree can carry out essential physiological processes optimally [20],[23]. Temperatures within these bounds facilitate nutrient uptake, photosynthesis, and overall metabolic activities, all of which are fundamental for healthy growth and fruiting. *A. moluccana*'s adaptability to varying altitudes, terrain types, and its specific requirements for rainfall and temperature make it a versatile tree species. These characteristics allow for successful cultivation across a range of geographic and climatic conditions, provided that the essential environmental parameters are met. Understanding these growth preferences is crucial for farmers and land planners when selecting suitable locations for *A. moluccana* cultivation.

4. Conclusion

In Gunung Ambat, Simpang Kuta Buluh, Rumah Galuh, and Telagah Village, the actual land suitability classes for *A. moluccana* were moderately suitable (S2) and marginally suitable (S3). The primary limiting factors in this area were the temperature (tc) and the characteristics of the root zone medium (rc). Regarding the potential land suitability classes for *A. moluccana* were classified as highly suitable (S1) in Land Unit 1, amounting to 21.51%; moderately suitable (S2) in Land Unit 4, 5, 6, 7, 8, and 9, making up 67.44% of the region; and marginally suitable (S3) in Land Unit 2, 3, and 10, comprising 10.96% of the land area. Through the execution of land suitability assessments for *A. moluccana* in community agroforestry areas, there is a promotion of sustainable land utilization, improvement of livelihoods, and preservation of natural resources.

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