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Suitability analysis of scrubland for arabica and robusta coffee plants in Aceh Besar Regency

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Abstract. This study aimed to analyze the land suitability for arabica (Coffea arabica) and robusta (Coffea canephora) coffee in scrubland in Aceh Besar Regency. This was implemented because the potential area of scrubs that were not utilized properly in Aceh Besar Regency reached 2,5330.6 ha. The data used in this study were secondary data and primary data, while data processing techniques were carried out by analyzing climate data, determining land map units, and taking soil samples in the field. Stages of combining several parameters were done by using Quantum GIS (QGIS) software using matching between land characteristics and land suitability class criteria. The results showed that the suitability of scrublands for coffee cultivation in the scrublands of Aceh Besar Regency was more suitable for robusta coffee cultivation, where after the improvement process was done, the potential land suitability to be moderately suitable (S2) with an area of 13,240.8 ha (52.3%), according to marginally suitable (S3) covering an area of 11,982 ha (47.3%) and not suitable (N) only an area of 107.8 ha (0.4%). The unsuitability limiting factor (N) for robusta coffee cultivation was only found at SPL 2 with Slope Class inhibition> 40%. As for the suitability of scrubland for Arabica coffee cultivation in Aceh Besar Regency, it had a fairly severe limiting factor on all land map units (SPL), including parameters of average temperature and altitude with no suitable class category (N), so the improvement process could not be done.

1. Introduction

Coffee is one of the leading agricultural products in Aceh Province. This condition makes the coffee agro-industry a strategic business for the community [1, 2]. One of the effects of the Aceh region's economic growth is the coffee commodity so that the improvement of the process in the coffee flow chain will simultaneously affect other stages of the process and ultimately improve the family economy, both coffee farmers, traders, and coffee powder producers. The development of coffee fields in Aceh Province based on data [3] is well developed in Bener Meriah, Gayo Lues, and Aceh Tengah regencies [4]. Apart from these 3 districts, Aceh Besar Regency also has the strategic potential [5]. Aceh Besar District has a coffee area of 1,761 ha with a production of 584 tonnes of coffee plants in 2018. Meanwhile, the largest producing area is Seulimeum Sub-district, with 123 tonnes or 21.06 per cent of the total coffee production in the Aceh Besar District.

Scrubland becomes less useful land for agriculture and plantations. The potential area of this unused land should be developed for plantation crops. However, plantation development should be based on good planning and structure. One method that is considered effective is by conducting a land suitability

class study in an area that is considered potential, so that land damage does not occur with decreased environmental function and economic losses in the future. This is also consistent with the statement of Lestari and Widayanti [6] who evaluated the level of land suitability to increase agricultural production and sustainably optimize land use.

The suitability analysis using the Geographic Information System (GIS) is considered effective and efficient because it represents climate elements, soil elements, and land topography so that this guideline only needs to be matched with certain plant growth requirements, and in this study was conducted for arabica and robusta coffee plants. A study of land suitability analysis of organic arabica coffee using GIS had also been conducted by Auliansyah et al. [7] in Pegasing Sub-district, Aceh Tengah Regency. One of the GIS applications that are easy to use is a free and lightweight platform for desktops that has limited capacity as the Quantum GIS (QGIS) software. As Hugentobler [8] argued, QGIS is a free and open-source desktop application for GIS that can process display data, editing, and spatial analysis. The purpose of this study was to analyze the suitability of land for Arabica (Coffea arabica) and robusta (Coffea canephora) coffee in scrublands in Aceh Besar Regency. This research was expected to contribute to the mapping of scrublands that have not been utilized so far but have the potential to be developed productively and sustainably in the future.

2. Materials and method

The research method used was land suitability guidelines from land evaluation techniques for agricultural commodities [9, 10]. The scoring of each climate parameter was based on the data from 2010-2019, since the latest spatial data matching method was not yet available, it was done by matching the suitability of the parameters used with the criteria for Arabica and robusta coffee plant. Then, the results of land suitability class decisions were selected based on a quantitative assessment and grouped based on the total score of all parameters. The matching process of the map overlay intersection results was done by using Quantum GIS (QGIS) software.

3. Result and Discussions

3.1. Results of Climate Parameter Analysis

The climate parameter is a determining parameter in land suitability analysis because if it becomes an inhibiting factor, of course, it will be very heavy or even improvement efforts can not be made, especially related to temperature and humidity factors. This is also by [11] based on the results of the analysis and studies proving that most people do not know the effect of temperature, rainfall, altitude, and soil conditions on the types of coffee plants so that coffee plants planted in a certain area often do not thrive, died, and often failed crops. Therefore, considering the importance of climatic factors, the data analysis for 10 years was used.

Based on the parameters of rainfall, it showed that robusta coffee was included in the moderately suitable class (S2), while for suitability Arabica coffee was included in the marginally suitable category (S3) (Table 1). Faradiba's research [12] stated that very high rainfall intensity has a significant effect on agricultural productivity, very low rainfall can also have a negative impact on crops. One of the concepts of soil and water conservation is to apply rainwater harvesting based on the results of the analysis of the rainfall required for forest plants. The results of the study [13] [14] stated that the rain harvesting system was able to control and store excess water in the rainy season and can be used by plants in the dry season. Rockström and Falkenmark [15] also stated that the rain harvesting system on agricultural land is one of the solutions to preventing hunger in their research in Africa.

On the parameter of the length of the dry period, it shows that the class was highly suitable (S1) for arabica and robusta coffee (Table 1). Besides, the parameter of mean air humidity (%) also supported robusta coffee with a highly suitable category (S1) and arabica coffee with a moderately suitable category (S2). Then for the average temperature parameter (%), robusta coffee was in a moderately suitable class (S2) and Arabica coffee was in the not suitable class (N). These results also ensured that

the main suitability of the scrublands in the studied area was the robusta coffee plant species rather than arabica coffee.

Table 1. Land suitability class parameters based on climatic factors

Parameter/Year	Average Year 2010-2019	Land Suitability Class	
		Robusta	Arabika
Rainfall (mm/year)	1,823.8	S2	S3
Length of dry period (month)	1.6	S1	S1
Average Air Humidity (%)	79.2	S1	S2
Average Temperature (%)	27.2	S2	N

Source: Results of the 2020 analysis, processed from BPS Aceh Besar (2011-2020)

3.2. Land Mapping Unit (SPL)

Land mapping unit (SPL) is a group of land which has the same or similar characteristics. Land characteristics are the characteristics that become data based on a combination of spatial data, including soil type maps, slope maps, and altitude maps. In a technical mix, an area that is too small below <0.5 ha is combined into characteristics that have the same 2 elements. The result was formed 18 units of land map units which can be seen in Table 2.

Slope and height are important parameters in land suitability analysis. According to Ritung et al. (2011) [10] the slope class parameter in coffee cultivation is below 30%. As for the altitude parameters, there are class differences, where Arabica coffee requires a higher altitude covering 1,000-2,000 masl. Meanwhile, Robusta coffee requires a lower altitude ranging from 0-900 masl [16]. The results of land suitability analysis based on parameters of slope class, altitude and erosion are presented in Table 2.

Table 2. Land Suitability Class Based on Slope, Altitude and Erosion Hazard Parameters

SPL	Slope Class (%)	LS of Slope for Arabica & Robusta	Altitude ASL (m)	LS of Altitude		Erosion Hazard	LS of Erosion
				Robusta	Arabica		
1	< 8	S1	0-100	S3	N	M	S2
2	>40	N	300 - 400	S1	N	H	S3
3	26 - 30	S3	100 - 200	S2	N	H	S3
4	8 - 15	S2	0-100	S3	N	M	S2
5	< 8	S1	100 - 200	S2	N	L	S2
6	8 - 15	S2	0-100	S3	N	M	S2
7	< 8	S1	300 - 400	S1	N	L	S2
8	8 - 15	S2	500 - 600	S2	N	M	S2
9	< 8	S1	0-100	S3	N	L	S2
10	8 - 15	S2	100 - 200	S2	N	M	S2
11	8 - 15	S2	100 - 200	S2	N	M	S2
12	< 8	S1	300 - 400	S1	N	L	S2
13	8 - 15	S2	300 - 400	S1	N	M	S2
14	< 8	S1	0 - 100	S3	N	L	S2
15	8 - 15	S2	100 - 200	S2	N	L	S2
16	< 8	S1	100 - 200	S2	N	L	S2
17	< 8	S1	0-100	S3	N	VL	S1
18	8 - 15	S2	100 - 200	S2	N	M	S2

Source: Results of the 2020 analysis, processed from the Erosion Data of the Krueng Aceh (BPDAS) (2015)
Information: LS =Land Suitability, L=low, VL=very low, M=medium, H=high, VH= very high

Cultivation of Robusta coffee on the inhibiting factor based on slope class, erosion, and altitude showed that it only occurred at SPL 2 with a not suitable class (N). The inhibiting factor for Arabica coffee cultivation was very high because all SPL suitability classes were not suitable (N) based on the altitude that was too low (<600 masl). For erosion hazard, it was in a class that supports coffee plantation

cultivation because each SPL was in the S1, S2 and S3 classes. However, it is still necessary to conserve water and soil, especially for marginally suitable classes (S3), as Nearing's opinion [17] emphasized the importance of soil and water conservation methods to be applied. The recommendation to develop coffee plantations on high erosion land (S3) was also by the results of the study by Rusdi et al. [18] where land with a high level of erosion hazard (B) needs to be handled by developing annual crop farming (plantation and industrial crops).

3.3. Soil Parameter
Soil parameter information is supporting information in coffee cultivation. This is because most of the soil parameter values were in class S1, S2, and S3, only soil texture and salinity were in class N (*Not Suitable*). Therefore, the results of the land suitability analysis were limited to the results of the soil texture analysis, C-organic and P205, which are presented in Table 3.

Table 3. Land suitability based on the soil parameter

SPL	Texture		C Organic			P205		Width (Ha)
	Class	R and A	(%)	R	A	Class	R and A	
1	F, SF	S1	1.4	S2	S2	H	S1	3,009.1
2	F, SF	S1	1.5	S2	S2	H	S1	107.8
3	SR	S3	1.5	S2	S2	VH	S1	385.2
4	F, SF	S1	1.4	S2	S2	H	S1	2,276.4
5	F, SF	S1	2.2	S1	S1	M	S2	755.0
6	F	S1	2.2	S1	S1	M	S2	358.1
7	M	S2	0.9	S2	S2	VL	S3	1,987.6
8	F, SF	S1	0.9	S2	S2	M	S2	310.0
9	F, SF	S1	1.0	S2	S1	L	S3	1,930.3
10	F, SF	S1	2.1	S1	S1	L	S3	534.1
11	F	S1	0.9	S2	S1	VH	S1	1,764.0
12	F, SF	S1	0.9	S2	S1	L	S3	6,587.3
13	F, SF	S1	0.8	S2	S1	L	S3	478.3
14	F, SF	S1	1.3	S2	S2	VL	S3	3,595.5
15	F, SF	S1	1.3	S2	S2	M	S2	133.3
16	F, SF	S1	1.4	S2	S2	M	S2	533.3
17	F, SF	S1	0.9	S2	S2	M	S2	427.4
18	F, SF	S1	1.0	S2	S2	M	S2	157.9
							Total	25,330.6

Source: The results of the analysis were processed from the Aceh Province Bappeda Data 2016
Information : F=Fine, SF=Slightly Fine,SR=Slightly Rough VH= Very High, H=High, M =Medium, L=Low, VL=Very Low

The results of the soil parameter analysis were very supportive of the cultivation of Arabica and robusta coffee lands. It can be seen that there were no analysis parameters included in the not suitable class (N). Generally, each land map unit was in the highly suitable (S1) and moderately suitable (S2) class, only SPL 2 was in the marginally suitable class (S3) on the limiting factor of soil texture.

3.4. Suitability of Actual and Potential Land for Arabica and Robusta Coffee
The actual land suitability of Arabica coffee as described in the explanation of air temperature and altitude indicated that each SPL was in the not suitable condition (N). Since the temperature and altitude parameters could not be applied to improvement efforts, thus the potential land suitability remained in the not suitable class (N) (Figure 1).
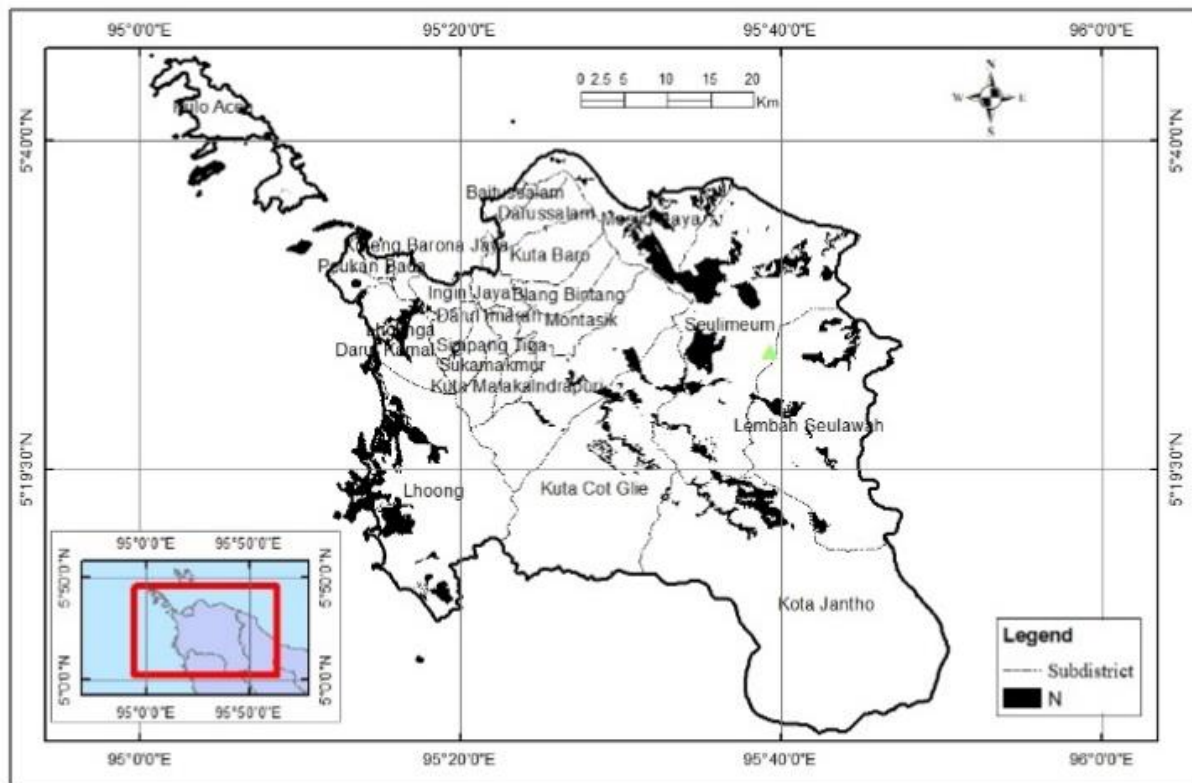
Figure 1. Suitability class for potential land of arabica coffee

The actual and potential land suitability of coffee from the results that had been described was more supportive of the cultivation of robusta coffee on scrubland in Aceh Besar Regency. The actual suitability class of Robusta coffee was in 3 classes, namely moderately suitable (S2), marginally suitable (S3), and not suitable (N) (Table 4). The moderately suitable class (S2) has an area of 3,653.6 ha (14.4%), the marginally suitable class (S3) has an area of 25,222.8 ha (85.2%), while the not suitable land class (N) has an area of 107.8 ha (0.4%) contained in SPL 2.

The improvement efforts of Robusta coffee cultivation by applying the concept of a rainwater harvesting system and supported by fertilization could increase the potential for land suitability to be moderately suitable (S2) with an area of 13,240.8 ha (52.3%), the marginally suitable (S3) of 11,982 ha (47.3%) and not suitable (N) with a fixed area of 107.8 ha (0.4%). The limiting factor for non-compliance (N) was only found in SPL2 with slope class inhibitors> 40% (Figure 2).

The spatial locations marked yellow for land suitability were moderately suitable (S2) (Figure 2). This was the best land for cultivation of Arabica coffee on scrubland so that it can be an alternative to additional coffee land from those already available in Aceh Besar Regency. Furthermore, the red color is a marker for the suitability of land in the marginally suitable class (S3), so it needs to be considered or needs to be re-examined in determining more suitable plantation land. As for black land with the not suitable class (N3), it is recommended that it is better conserved for protected areas because it is on a slope> 40%, as regulated by the Ministry of Agriculture [19].

Table 4. Suitability of actual and potential land of robusta coffee

SPL	Land suitability of robusta Coffe			Width (Ha)
	Actual	Improvement	Potential	
1	S3 tc-2	-	S3 Tc-2	3,009.1
2	N eh-1	-	N eh-1	107.8
3	S3 rc-1, eh-1, eh-2	RH	S3 eh-1, rc-1	385.2
4	S3 tc-2	-	S3 tc-2	2,276.4
5	S2 tc-1, tc-2, wa-1, na-2, eh-2	RH, F	S2 tc-1. tc-2	755.0
6	S3 tc-2,	-	S3 tc-2	358.1
7	S3 na-2	F	S2 wa-1, na-2, tc-1	1,987.6
8	S2 tc-1, tc-2,wa-1, tc-1, tc-2, eh-1, eh,-2	RH, F	S2 tc-1, tc-2, eh-1	310.0
9	S3 tc-2, na-2	F	S3 tc-2	1,930.3
10	S3 na-2	RH, F	S2 tc-1, tc-2, na-2, eh-1	534.1
11	S2 tc-1, tc-2, wa-1, nr-4, eh-1, eh-2	RH, F	S2 tc-1, tc-2, eh-1	1,764.0
12	S3 na-2	F	S2 tc-1, wa-1, nr-4, na-2, eh-2	6,587.3
13	S3 na-2	F	S2 wa-1, na-2, tc-1	478.3
14	S3 tc-2, na-2	F	S3 tc-2	3,595.5
15	S2 tc-1, tc-2, wa-1, nr-4, na-2 eh-1, eh-2	RH, F	S2 tc-1, tc-2,eh-1	133.3
16	S2 tc-1, tc-2, wa-1, nr-4, na-2, eh-2	RH, F	S2 tc-1, tc-2	533.3
17	S3 tc-2	-	S3 tc-2	427.4
18	S2 tc-1, tc-2, wa-1, nr-4, na-2 eh-1, eh-2	RH, F	S2 tc-1, tc-2,eh-1	157.9
	Total			25,330.6

Information : tc-1= average temperature , tc-2= altitude, wa-1= rainfall, wa-2=dry months, rc-1=soil texture, na-2 =P205, nr-4=C-organic, eh-1=slope, eh-2=erosion hazard, RH= rainwater harvesting, F= fertilization, S1 = highly suitable, S2=moderately suitable, S3= marginally suitable, N = not suitable
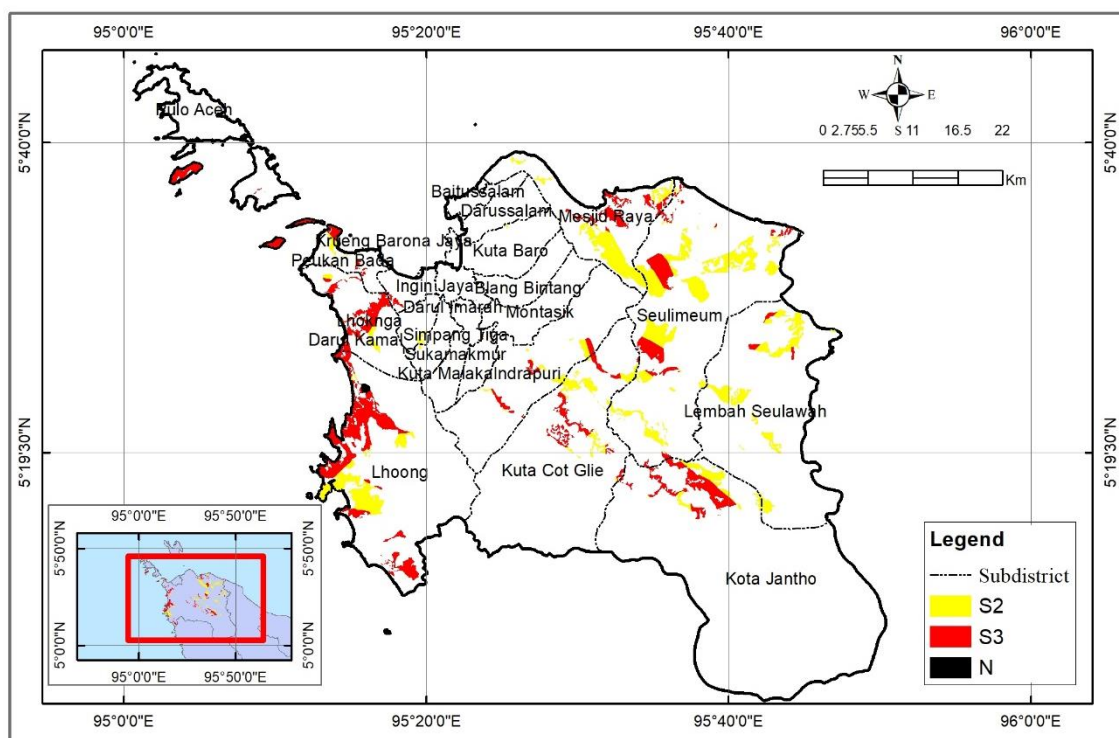
Figure 2. Suitability class for potential robusta coffee lands

4. Conclusion

The suitability of scrubland for Arabica coffee cultivation has a fairly severe limiting factor, namely the average air temperature and altitude in the not suitable category (N) and no improvements can be made for the parameters of air temperature and altitude, so the potential suitability class remained (N) in Arabica coffee cultivation on scrubland.

The suitability of scrublands for coffee cultivation in the scrublands of Aceh Besar Regency was more suitable for robusta coffee cultivation, where the actual suitability class was moderately suitable (S2) 3,653.6 ha (14.4%), marginally suitable (S3) with an area of 21,569.2 ha (85.2%) and not suitable (N) with an area of 107.8 Ha (0.4%). After the improvement efforts on the potential land suitability, the scrubland could be increased to be moderately suitable (S2) with an area of 13,240.8 ha (52.3%), marginally suitable (S3) 11,982 ha (47.3%), and not suitable (N) only 107.8 ha (0.4%). The limiting factor for the not suitable scrubland (N) was only found in SPL2 with slope class inhibitor> 40%.

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