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Assessment of Land Characteristics and Recommendation for Improvements in Patchouli Plantations in Aceh Province, Indonesia

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ABSTRACT

Background: Land characteristics and its criteria are important factors affecting the success of crop cultivation. This research aimed to evaluate the value and criteria of land characteristics for Aceh patchouli.

Methods: The study was conducted at smallholders' adopting patchouli farming in North Aceh (AU) and Gayo Lues (GL) using purposive sampling method. Eleven patchouli farming in both AU and GL were selected. Soil sampling and agroclimate data were collected from the farming.

Result: The results revealed that the altitude varied at each plantation and there were significant differences of altitudes, climates and soil characteristics between plantations in those two regions. It is found that the land characteristics in AU and GL of patchouli plantations are classified into marginally suitable (S3) and not suitable (N). But, the best class for patchouli lies between S1-S3, where S3 class requires adequate rainfall and organic-C, enabling the land to upgrade its class, to be resulted in an increase of patchouli production. The best patchouli growth and production was determined by land characteristics like base saturation (BS), total-N, erosion hazard, stoniness and rocks outcrop and have been evaluated and suitable suggestions were given.

Key words: Criteria of land characteristics, Land characteristics requirements, Land suitability class, Patchouli.

INTRODUCTION

Patchouli (*Pogostemon cablin* Benth) is considered as prospective aromatic plant for its essential oil. Indonesia is the world's largest producer of patchouli, 90% of global market in the world, contributing to the increase of national economy in Indonesia (Nasruddin *et al*., 2020). The demand of patchouli oil is increasing, as this oil has been used as fixative agent in cosmetic, perfume and soap industries. Unfortunately, the patchouli production in Indonesia still unable to meet the great demand of this commodity in global market as the production has continued to decrease in the last 4 years (Dirjenbun, 2018). Patchouli production varies between places in Indonesia. The highest was found in Sumatra Utara and Aceh Provinces. The data collected by Dirjenbun (2018) for the last 4 years (2014-2017) revealed the production in Sumatra Utara reached up 215.34 kg/ha/year, followed by Aceh (211.80 kg/ha/year) and other places (<140.00 kg/ha/year). Aceh patchouli oil demonstrated better quality compared to oil produced from patchouli in Sumatra Utara, enables Aceh patchouli to become more popular worldwide. Acehnese patchouli exhibited rendement 2-3% and patchouli alcohol 30%. These characteristics have lead Acehnese patchouli to be the main supplier of patchouli oil in Indonesia (±70%) (Ayu *et al*., 2016).

The oil production 211-215 kg/ha/year is considered low. It is only 60% from the potential exhibited by Tapaktuan, Lhokseumawe and Sidikalang varieties, where they usually produce 375.76, 355.89 and 315.95 kg/ha/year (Pujiharti *et al*., 2008). The oil production and quality are possible to be increased by evaluating its land characteristics, where these characteristics influence the patchouli growth, production and quality. Land characteristics for patchouli were released by Rosman *et al.* (1998) and Ministry of Agriculture (2014). However, these characteristics considered inadequate as they did not mention humidity, wet season, base saturation and nitrogen. Ritawati *et al.* (2019) and Setiawan *et al*. (2021) also did not mention base saturation and nitrogen. Temperature, rainfall, humidity and wet season play a crucial role in the plant growth and yield (Pugnaire *et al*., 2019). Base saturation and nitrogen are needed to be considered in land characteristics as they greatly influenced the plant growth and yield (Wahyunto *et al*., 2016). Base saturation represents soil fertility and nitrogen is important for plant physiology (Havlin *et al*., 2013; Gojon, 2017; Meshram *et al*., 2019). Therefore, we conducted this

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research to classify land suitability class for patchouli in AU and GL districts in order to establish the best land suitability for Acehnese patchouli.

MATERIALS AND METHODS

Study area, time, tool and materials

The research was conducted in September-November 2020 at smallholders' farming in AU and GL Regencies, Aceh Province, Indonesia (Fig 1). Geographically, the territory of AU stretch from 96°.52′.00″ to 97°.31′00″E longitude and 04°.46′.00″ to 05°.00′.40″N at an altitude of 263-674 m asl, while GL stretch from 96°.43′.15.65″ to 7°.55′.24,29″E longitude and 03°.40′.46,13″ to 04°.16′.50.45″N at an altitude of 641-869 m asl.

The material used in this research for survey, soil analysis *etc* were H_2O, HCl 30%, natrium pyrophosphate ($Na_4P_2O_710H_2O$), distilled water, $K_2Cr_2O_71N$, concentrated H_2PO_4, H_3PO_7 85%, $FeSO_4$ 1N and NH_4OAc 1N. The tools used were soil auger kit, hoe, machete, knife, bayonet knife, used magazines, compass, measuring tape, transparent plastic (size 1 kg), labeled paper, GPS (*Global position system*), *abney level,* camera, stationery, computers and maps (land use map, administrative map, slope and soil maps).

Data collection

The data collected in this research was divided into primary and secondary data. Primary data described soil characteristics, patchouli growth (plant height, number of primary and secondary branches), oil production and quality (level of patchoulol). Secondary data showed us patchouli production of a soft production that lacks of leathery woods, collected by local farmers and staff from the Department of Agriculture and Plantation in those regencies, along with climatic data obtained from climate stations located in Malikussaleh, North Aceh and Indrapuri, Aceh Besar. Braak formula (1928) in Ritung *et al.* (2007): T = t°C-(0.61°C × h × 0.01) was employed to estimate air temperature of selected research places.*t*is average temperature per year (26.63°C), obtained from climate station Malikussaleh, North Aceh. This average temperature was used to forecast the temperature on the research sites. The identification of soil characteristics and its environment such as the elevation, soil depth, drainage, the slopes, the erosion hazard, stoniness and rocks outcrop were carried out at 22 patchouli plantations, 11 plantations in AU (AU1-AU11) and 11 plantations in GL (GL1-GL11). Peat thickness, salinity, alkalinity and sulfidic depth were not assessed due to the land did not show those characteristics. Purposive sampling method was used in the selection of research site. The soil samples were taken from each plantation at a depth 0-30 cm using soil auger kit. All samples (22 samples) were air dried and then sieved using sieve 2 mm (10 mesh) to determine the physical properties of the soil such as soil texture 3 fraction (hydrometer) and the chemical properties such as soil pH (w/s:2.5:1) using pH meter (model WTW 330i/Germany), organic-C (Walkley and Black), total-N (Kjedahl), level of P_2O_5 (Extract HCl 25%), level of K_2O (Extract HCl 25%), cation exchange capacity-CEC (NH_4OAc pH 7.0) and BS (NH_4OAc pH 7.0) at Assessment Institute for Agricultural Technology (AIAT) Sumatra Utara.

Determination of land suitability class

The land suitability class was determined by matching the land characteristics of each plantation with the criteria of land suitability which has been modified and required by Rosman *et al.* (1998) and Ministry of Agriculture (2014). Nutrient retention of BS and total-N are considered as land characteristics influencing the growth and yield of patchouli specifically. Furthermore, the determination of the best land suitability for patchouli refers to land characteristics with the highest growth and yield. The developed criteria of land

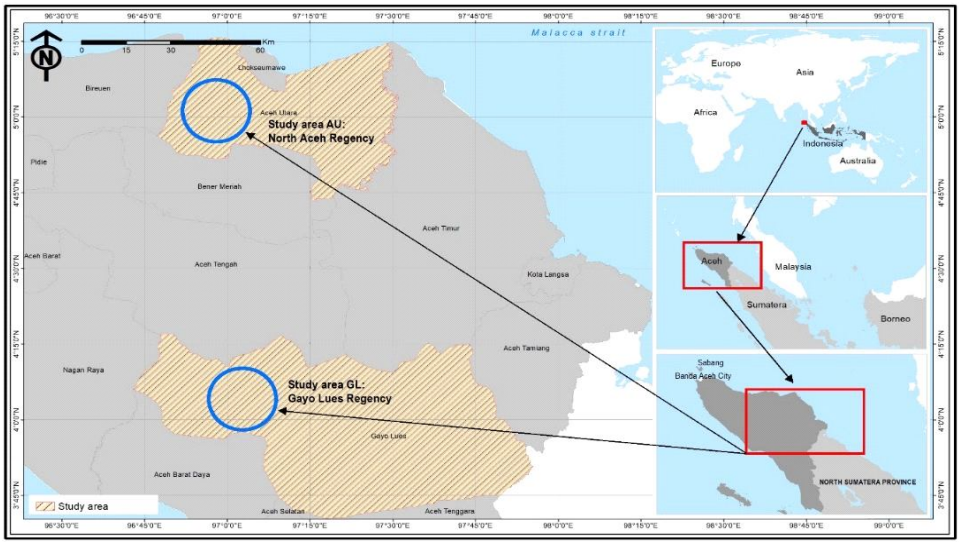

Fig 1: Map of study area.

characteristics for patchouli have considered nutrient retention of BS and total-N as important aspects to be assessed.

RESULTS AND DISCUSSION

Land characteristics

The results showed the differences on elevation, temperature, rainfall and wet season between AU and GL. The plantations are located in lowland and highland (263-869 m asl), where average annual temperature is 25.03°C. AU demonstrated higher temperature (26.46°C) compared to GL (21.33°C), rainfall rate in AU is lower (1490.3 mm) compared to GL (1809.3 mm). Also, the wet season in AU is lower (8 months) compared to GL (11 months). However, both plantations have well to moderate drainage, dominated by sandy loam. Its soil depths are varied (40-90 cm). The shallowest (40 cm) was found in plantation AU9, AU10 and GL7, where this condition was found to be a constraint. Chemical, physical and biological properties in soil are important for plant growth, oxygen and nutrients availability (Fadlalla and Elsheikh, 2016; Meena *et al*., 2016).

CEC value varied between 4.55-30.99 cmol (+)/kg, where the lowest found in AU 3 and the highest in AU1. Base saturation was between 23.55-332.75%, which the lowest found in GL8 and the highest in AU3. pH valued between 4.70-8.13, the lowest in GL8 and the highest in AU3. Organic-C was between 0.94-5.47%, where the lowest in AU3 and the highest in AU1. N, P, K elements also varied. N element was 0.06-0.50%, where the lowest found in AU2 and the highest in AU1. P element was 4.02-33.86 ppm, where the lowest found in GL9 and the highest in GL3. K element was 0.25-1.86 me/100 g, the lowest found in AU3 and the highest in AU6. The variety of characteristics found in the study site was influenced by parent material, low organic matter and intensive cultivation (Soares *et al*., 2005; Parikh and James, 2012). The slopes were between 5.24-16.73%, the minimum in AU1, AU5, GL1 and GL2 and the maximum in GL10. Stoniness <7% in AU2 and outcrop rocks 3% in AU9, AU10 and GL6.

Classification of land suitability

In this study, we classified land suitability through examining the data collected and modifying the established land suitability by Rosman *et al*. (1998) and Ministry of Agriculture (2014). The results were presented in Table 1, showing the land classes were marginally suitable (S3) and not suitable (N). S3 class demonstrated several limiting factors such as altitude, erosion hazard, temperature, water availability, root media and nutrient retention, while N class possessed erosion hazard, root media and nutrient retention as its

Table 1: Land suitability classes for patchouli in AU and GL regencies.

Site/farm	Land suitability classes	Limiting factors	Land improvements	Level of soil improvement
AU1	S3wa-1	Rainfall	Irrigation	M (+); H (++)
AU2	S3wa-1,eh-1,na-1	Rainfall, slope, N	Irrigation, SWC, N- fertilizer	M (+); H (++)
AU3	Nnr-3	pH	Liming	M (+); H (++)
AU4	S3wa-1,eh-1,nr-4,na-1,2	Rainfall; org-C; slope	Irrigation; OM; SWC; N and P- fertlizers	M (+); H (++)
AU5	S3wa-1,nr-1,2,na-2,3	Rainfall; CEC; BS; N; P	Irrigation; OM, liming, N and P- fertilizers	M (+); H (++)
AU6	Neh-1	Slope	SWC	M (+); H (++)
AU7	S3wa-1,eh-1,na-2	rainfall; slope; P	Irrrigation; SWC; P- fertilizer	M (+); H (++)
AU8	S3rc-2,wa-1,eh-1,na-2	Sd; rainfall; lope; P	Irrigation; SWC; P- fertilizer	M (+); H (++)
AU9	Nrc-2	Sd	-	-
AU10	Nrc-2,nr-3	Sd; pH	-	-
AU11	S3rc-2,wa-1,eh-1,	Sd; rainfall; slope	Irrigation, SWC	M (+); H (++)
GL1	S3tc-1,nr-4	Temperature; org-C	OM	M (+); H (++)
GL2	S3rc-2,tc-1,nr-4,na-1	Sd; temperature; org-C; N	OM; N- fertilizer	M (+); H (++)
GL3	Nnr-3	pH	Liming	M (+); H (++)
GL4	S3el-1,tc-1,eh-1,na-1,2,3	Altitude; temperature; slope, N,P,K	SWC; N,P,K- fertilizers	M (+); H (++)
GL5	S3el-1,tc-1,eh-1,nr-4,na-1,3	Altitude; temperatur; slope; org-C,N,K	SWC; OM; N and K- fertilizers	M (+); H (++)
GL6	S3el-1,tc-1,eh-1,nr-4,na-1,2	Altitude; temperature; slope; org-C,N,P	SWC; OM; N and P- fertilizers	M (+); H (++)
GL7	Nrc-2	Sd	-	-
GL8	Neh-1	Slope	SWC	M (+); H (++)
GL-9	Neh-1	Slope	SWC	M (+); H (++)
GL10	Neh-1	Slope	SWC	M (+); H (++)
GL11	S3el-1,tc-1,eh-1,na-1	Altitude; temperature; slope; N	SWC; N- Fertilizer	M (+); H (++)

Notes: CEC -(cation exchange capacity); BS- (base saturation); N -(nitrogen); P- (phosphorus); K- (potassium); OM- (organic matter); SWC- (soil and water conservation technology ie silt pits, mounds; terrace); M- (moderate); H- (high); -- (hard to fix); + (land improvements can elevate the grade one level higher, S3 to S2); ++ (promotion to two levels higher, S3 to S1); Sd-Soil depth; pH-Soil pH.

Table 2: The data of growth, production and alcohol content of patchouli in AU and GL Regencies.

Site/Farm	Plant height (cm)	Number of branches		Oil product (kg ha^{-1} year^{-1})	Content of alcohol (%)
		Primary	Secondary		
AU1	94.33	7	25	240	30.43
AU2	91.33	13	43	230	31.92
AU3	102	18	45	225	30.78
AU4	114.3	10	56	233	33.26
AU5	81.67	9	67	235	31.89
AU6	98.33	8	56	229	33.36
AU7	80.67	9	29	235	32.54
AU8	89.33	6	51	232	33.23
AU9	98.67	9	67	219	31.79
AU10	101	9	51	221	33.23
AU11	95.17	10	64	237	32.24
GL1	85	16	49	345	29.84
GL2	75	19	49	348	30.01
GL3	85.67	16	86	340	29.78
GL4	85.67	6	39	348	28.98
GL5	66.67	11	65	348	29.75
GL6	100	18	65	347	28.39
GL7	51.67	9	24	332	28.45
GL8	101.7	11	32	343	28.78
GL9	80.67	7	15	340	30.01
GL10	78.67	14	53	339	29.45
GL11	81.07	17	56	348	29.34

limiting factors. In AU, patchouli planted at S3 class experienced slope, rainfall, organic-C, pH and CEC, while at N class, the plants experienced slope, soil depth and pH. In GL, S3 class exhibited several limiting factors such as altitude, temperature, slope and organic-C, while N class demonstrated similar condition shown in AU. Altitude, temperature and soil depth are un-improvable. Soil slopes in AU and GL have been improved through applying soil conservation by building silt pits and mounds and planting avocado. Therefore, the N classes in GL possessed with slope did not affect the patchouli growth and yield. Similar phenomenon also occurs in S3 classes in AU and GL where at slope <25% there is possibility to cultivate crops as the conservation applied properly to support the plant growth (Chen *et al*., 2020).

CEC and organic-C in S3 class in study sites observed were improved by applying organic matter. However, it needs to be increased and continued to optimize the organic matter in the soil. Organic matter significantly improves the soil's capacity to store and supply essential nutrients and carbon and also it enhances CEC and water infiltration (Havlin *et al*., 2013).

Value of land characteristics for patchouli plantation

The growth, production and the quality of patchouli oil were determined by the value of land characteristics for patchouli (Table 2), where the best and highest growth, production and quality of patchouli oil were often found in lands with distinctive characteristics. The land characteristics and values were presented in Table 3.

Table 3: Land characteristics and Index values for patchouli plantation.

Land characteristics	Index values
Altitude (m. a.s.l)	326-644
Annual temperature average (°C)	22.72-25.03
Annual rainfall average (mm)	1809.3-1490.3
Wet month	3-11
Humidity (%)	82.22-86.66
Drainage	Well drainage, -moderate
Soil texture	Sandy loam, loamy
Soil depth (cm)	>80
Cation exchange capacity (cmol (+)/kg)	12,21-30,99
Base saturation (%)	80-100
Soil pH H_2O	6.14-6,63
Organic-C (%)	1.58-5.47
Total-N (%)	0.24-0.53
P_2O_5 (ppm)	18.41-24.39
K_2O (me/100 g)	0.76-1.93
Slope (%)	<5.24
Erosion hazard	Very light, -moderate
Stoniness (%)	5-17
Rock outcrops (%)	3-12

Data in Table 4 presented the best land characteristics required for patchouli in AU and GL. Each characteristic was classified into S1, S2 and S3 classes. The land in S3 class was characterized by its rainfall 1490.3 mm which found AU plantations, where it is possible to be improved by irrigation, silt pits forming, bio-pores and retention basin to maximize water availability in the soil. The water is essential for nutrient

absorption, biota activities and plant physiology (Razaq *et al.*, 2017; Weih *et al.*, 2018). The organic-C 1.58% found in GL1 also has been fixed by the provision of organic matter in the soil, resulting in an increased yield from 316 kg/ha/year to 375 kg/ha/year. Organic-C is also crucial for enhancing soil properties, attributed to soil fertility and productivity (Jacoby *et al.*, 2017; Johns, 2017; Elayaraja and Sathiyamurthi, 2020).

Table 4: Criteria of land suitability classification for patchouli.

Land qualities/land characteristics	Land suitability classes			
	S1	S2	S3	N
Elevation (el)				
Altitude (m. a.s.l)	100-400	0-100; 400-700	700-800	>800
Temperature (tc)				
Annual rainfal average (°C)	22-23	24-25	19-21 and26-27	<19 and>27
Water availability (wa)				
Annual rainfall average (mm)	2.300-3.000	1.750-2.300	1.200-1.750	<1.200
Wet season (month)	10-11	8-9	7	<7
Humidity (%)	80-90	70-80	50-60	<50
Oxygen avaibility (oa)				
Drainage	Well	Moderate	Poorly	Very poorly
Root retention (rc)				
Soil texture	l; scl; sicl	sc; cl	sic;sl	s;c
Soil depth (cm)	>100	75-100	50-75	<50
Nutritions retention (nr)				
CEC (cmol(+)/kg)	>17	6-17	<6	-
Base saturation (%)	>80	51-80	20-50	<20
Soil pH H_2O	5.5-7.0	5.0-5.4	4.5-4.9	<4.5
Organic-C (%)	2.0-3.0	3.1-5.0	1.0-1.9	<1.0
Nutritions availability (na)				
Total-N (%)	0.51-0.75	0.31-0.50	0.21-0.30	<0.21
P_2O_5 (ppm)	15-25	10-15	>25	-
K_2O (me/100g)	>1.0	0.6-1.0	0.2-0.5	<0.2
Erosion hazards (eh)				
Slope (%)	0-2	2-8	8-15	>15
Erosion hazard	Very light	Light–moderate	Heavy	Very heavy
Land preparation (lp)				
Stoniness (%)	<5	5-12	12-35	>35
Rock outcrops (%)	<5	5-12	12-25	>25

Note: l (loam); scl (sandy clay loam); sicl (silt clsy loam); sc (sandy clay); cl (clay loam); sl (sandy loam); s (sand); c (clay).

Table 5: Correlation between land characteristics and patchouli growth and yield.

Land characteristics	Growth and yield of patchouli					
	Y1	Y2	Y3	Y4	Y5	Y6
Altitude (m.asl)	-.31	.44*	.04	-.04	-.71**	.68**
Temperature (°C)	.31	-.44*	-.04	.04	.71**	-.68**
Rainfall (mm/year)	.52*	.47*	.38	-.09	-.87**	.87**
Humidity (%)	.52*	.47*	.38	-.09	-.87**	.87**
Wet season (moon)	.52*	.47*	.38	-.09	-.87**	.87**
Sand	-.13	.15	.06	-.38	-.45*	.34
Silt	.27	.21	.06	.32	.44*	-.26
CEC (cmol(+)/kg)	.05	.33	.55**	.21	.18	.08
Organic-C (%)	.03	.28	.65**	.01	.26	.24
pH	.26	.48*	.52*	.22	.07	.04
Total-N(%)	.03	.43	.57*	.02	.28	.19
P_2O_5 (ppm)	.13	.77**	.40	.29	.34	.54*
Stoniness (%)	.21	-.25	.03	-.15	.17	-.49*
Rock outcrop (%)	-.40	.01	.01	.10	.11	-.43*

Note: **Significant at 0.01; *Significant at 0.05; Y1= Plant height; Y2= Number of leaves; Y3= Number of primary branches; Y4= Number of secondary branch; Y5= Patchouli alcohol; Y6= Productivity.

Recommendation of criteria of land characteristics requirement for patchouli plantation

We were trying to enhance the land characteristics required for patchouli plantation, where these indicators were a modification from land suitability requirement released by Rosman *et al*. (1998) and Ministry of Agriculture (2014) with adjusting several suitable characteristics such as altitude, temperature, wet season, drainage, soil texture and formation, soil depth, CEC, pH and organic-C. We also considered BS, total-N, the erosion hazard, stoniness and rock outcrops to be assessed.

The modified and improved land characteristic requirements for patchouli was revealed in Table 4, where the requirements have been appointed based on this research in the sites, the correlation between land characteristics and patchouli growth and yield (Table 5) and also the evaluation of soil fertility at the plantation. The land characteristics we assessed from each land suitability class attributed to the growth and yield of patchouli.

CONCLUSION

The elevation and climate varied with plantations and showed differences between the plantations AU and GL, where patchouli has been grown in highlands (>700 m asl) in GL. That contributed to differences in land characteristics and AU and GL.

Land suitability in AU and GL was classified into S3 (marginally suitable) and N (not suitable). N class was found at AU6, AU9 and AU10, while in GL was found at GL3, GL7, GL8, GL9 dan GL10. The plantations with maximum slope (GL8, GL9 and GL10) have been upgraded using conservation technology, while in AU (AU9 and AU10), its soil depth was unfixable. The pH value in GL3 has been lowered through application of organic matter.

The best criteria and land indicators in Aceh were laid between S1-S3 classes with implementation of land improvements. However, this study offers scope for further improvements by adding base saturation, total-N, the erosion hazard, stoniness and rockoutcrops as essential land characteristics to ensure higher production of patchouli oil.

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