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I. Manuscript Title

A COMPARISON OF LAND SUITABILITY VALUES FOR ENDEMIC LIBERICA COFFEE WITH DIFFERENT METHODS, AND THEIR IMPACT ON LAND MANAGEMENT IN THE PINOGU PLATEAU, BONE BOLANGO REGENCY

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VIII. The main findings and why they are important and useful.

1. Land suitability class for liberica coffee in Pinogu Plateau is the result of research that was first produced in this region and in the province of Gorontalo, both with the limiting factor method and the parametric method. Thus, the results are very important in planning and sustainable land use for liberica coffee as well as for land management in this region given its position as the upstream of the Bone watershed.

2. It turns out that the land suitability class using the parametric method is more sensitive and approaches the profitability conditions of Liberica coffee which are more real in the field, so that it has an impact on land management inputs that are less than the limiting factor method. Consequently, by using the land suitability class as a result of the parametric method, Liberica coffee farmers will get the efficiency of their plantation business.
3. The use of the coffee profitability estimating equation is proven to be able to produce profitability values that are close to the existing conditions of profitability for liberica coffee, so that the limitations of profitability data on land units can be overcome.

IX. Why the readers of the journal would be interested in the work.

1. Liberica coffee is a refreshing commodity that is strategic and closely related to the daily life of coffee lovers, so its availability is needed both nationally and globally. Thus, efforts to develop coffee by intensification and extensification on existing and potential land in a sustainable manner will always be carried out.
2. Readers will obtain information on the potential of land resources through land suitability for liberica coffee, so that the information will become a reference for the parties to increase the production and profitability of liberica coffee in a sustainable manner.
3. Readers will get a choice of adequate information about the results of the land suitability assessment for liberica coffee using the limiting factor method and the parametric method, so that later decision making will be wiser and wiser, especially with regard to Pinogu Plateau's position as the headwaters of the Bone watershed.

X. Suggested Reviewers : *(at least 2 reviewers)*

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A COMPARISON OF LAND SUITABILITY VALUES FOR ENDEMIC LIBERICA COFFEE WITH DIFFERENT METHODS, AND THEIR IMPACT ON LAND MANAGEMENT IN THE PINOGU PLATEAU, BONE BOLANGO REGENCY

ABSTRACT

Coffee is a national strategic commodity that contributes to the country's foreign exchange but these profitability is still low due to cultivation on low potential land. Study aimed to determine the land suitability value of endemic liberica coffee with two different methods and their impact on land management in Pinogu Plateau. The 13 land units were surveyed and analyzed the soil samples in the laboratory to obtain data of the land characteristic selected. Comparison of different land suitability values using the limiting factor method and the parametric method. The results showed that the land suitability class for liberica coffee using the limiting factor method actually consisted of a moderately suitable class (S2) and a marginally suitable class (S3) with elevation, nutrient retention and available nutrient constraints. Efforts to improve the class by adding organic matter and fertilization, so that it has the potential to become a very suitable class (S1) and S2 class. Meanwhile, the land suitability class using the parametric method consisted of S1, S2 and S3 classes due to low P nutrients. The input for land management with the parametric method was P fertilization only compared to the limiting factor method that more input of land managements.

Keywords: Land, suitability, coffee, liberica, endemic, Pinogu.

INTRODUCTION

Coffee is still a strategic commodity for Indonesia because it can contribute to the country's foreign exchange from the export value of the commodity. Until 2020, national coffee production reached 753,941 tons, an increase of 0.19% from the previous year, while exports of national coffee commodities reached 375,555.9 tons or increased by 2.62% from the previous year with a value of 809,158,900 US$ (BPS, 2020). From this achievement of national coffee production, the contribution of Gorontalo Province is only 139 tons or 0.02% of the total national coffee production (Ditjendbun, 2021).

Pinogu is one of the sub-districts in the Bone Bolango Regency, Gorontalo Province which is relatively flat and wide (496 km2) at an altitude of > 300 m above sea level, and is surrounded by hills and mountains so that it can be called the Pinogu plateau. This district has long been known as a coffee producer, even since the Dutch colonial era (Sancayaningsih et al., 2016; Humola et al., 2021). According to Ahmad & Paserangi (2018), almost every family in Pinogu Plateau owns a coffee plantation and makes it their main commodity because the productivity level of this coffee is the highest compared to other commodities. Pinogu coffee has a distinctive taste, including: a more fragrant aroma, tastes like jackfruit with a moderate acidity level, so it is not too bitter and is safe in the stomach (Liputan6.com, 2017). The advantages of pinogu coffee include the fact that local farmers do not use pesticides, herbicides or other chemical fertilizers in coffee cultivation (Zainuddin, 2020), so this coffee can be said to be organic coffee (Fatmalasari et al., 2016). Pinogu coffee comes from robusta coffee and liberica coffee (Zainuddin, 2020; Susilo et al., 2021).

Liberica coffee (Coffea Liberica) has been planted since 1875 (Sancayaningsih et al., 2016) and is endemic because this species only exists and grows in an area (KBBI, 2021) in this case in Pinogu District only for Gorontalo Province. Liberika coffee has the advantage of good taste (Gusfarina, 2014), relatively low caffeine content (1.1-1.3%), so it is safe for consumers who are sensitive to caffeine (Puslitkoka, 2014). This condition makes pinogu coffee an icon and superior commodity of Bone Bolango Regency (Zainuddin, 2020).

Efforts to maintain the sustainability of liberika coffee products have so far encountered several obstacles, one of which is the low profitability of the coffee. Martono (2018) reports that although Pinogu Coffee has become global, its profitability is still low at only 0.75 tons ha^{-1} $year^{-1}$. In fact, the profitability of liberica coffee can reach 1.69 – 1.98 tons ha^{-1} (Balittri, 2015). The report of BPS Kabupaten Bone Bolango (2021) shows that Pinogu District has a coffee plantation area of 282.63 ha or the largest in this district (66.21%) with new production of 32.43 tons. Such conditions will affect the availability of coffee raw materials to meet market demand later. The low profitability of coffee is thought to be because coffee cultivation is carried out on land that is not in accordance with the potential of the land. Land potential is generally determined based on the characteristics and quality of the land inherent in the land (Nurdin, 2021).

Until now, there is no available information about the potential of land for the development of Liberika Coffee in the Pinogu Plateau area, except for the potential of land for Robusta coffee because it is more developed as a research report by Taslim (2018); Indrianti (2020) and Humola et al., (2021). Even though this liberica coffee is not only endemic, it is also more resistant to pests and plant diseases (Harni et al., 2015), resistant to leaf rust and somewhat resistant to coffee berry borer pests (Gusfarina, 2014; Balittri, 2015). Ignorance of coffee planters regarding land potential will greatly affect the profitability of the land in supporting the growth and production of liberica coffee itself. Diversity of land characteristics and quality will be responded differently by each plant because each land-based commodity requires certain requirements to be able to grow and produce optimally (Rayes, 2007; Ritung et al., 2011).

Sustainable land management requires land evaluation methods that contain plant growth requirements for optimal production (Suryani, 2012) through land suitability assessment so that a land can be used productively and sustainably (Mustafa et al., 2014), including land suitability assessment for Liberika Coffee. However, often the results of land suitability assessments do not match the facts of actual production achievements in the field (Nurdin, 2021). Previous research on land suitability assessment for coffee mostly used the limiting factor method. The limiting factor method is used to determine the class based on the lowest constraint, while the parametric method is determined based on the interaction between all variables (Baja, 2012). In the parametric method, there is a combination of soil characteristics that affect agricultural production using mathematical equations (Elaalem, 2013) so that interactions between land characteristics can be minimized. Furthermore, Bagherzadeh & Gholizadeh (2016) stated that in the parametric approach, different land suitability classes are defined as completely separate groups and separated from each other with different and consistent ranges. Differences in land suitability values due to the use of different methods on a land will have an impact on differences in land management. Therefore, the aim of the study was to determine the land suitability value of endemic liberica coffee with two different methods and their impact on land management in Pinogu Plateau, Bone Bolango Regency.

MATERIAL AND METHODS

Site Study

This research was conducted in Pinogu Plateau, Bone Bolango Regency, Gorontalo Province. Geographically, the research location is located at 0°24'5.4" – 0°38'29.04" North Latitude to 123°18'38.52" – 123°33'15.48" South Latitude covering an area of 2,804.28 ha with an elevation of 300 – 338 m above sea level (Fig. 1). Annual rainfall is 2,541.90 mm with an average monthly rainfall ranging from 19.00 mm to 408.18 mm (BPP Pinogu District, 2021), so based on the agro-climatic zone (Oldeman and Darmiyati, 1977), the research area is included in the agro-climatic zone. C1 because the dry month (<100 mm) is only 1 month and 6 months is wet (>200 mm). The monthly air temperature in the study area fluctuates between 24.34°C to 25.79°C while the relative humidity is between 78.60% to 84.40% and the duration of monthly sunshine is between 44.52% to 70.50%. while the monthly wind speed is between 2 knots to 2.60 knots (BMKG Moutong, 2021). The research area is the upstream of the Bone watershed which flows to Tomini Bay.

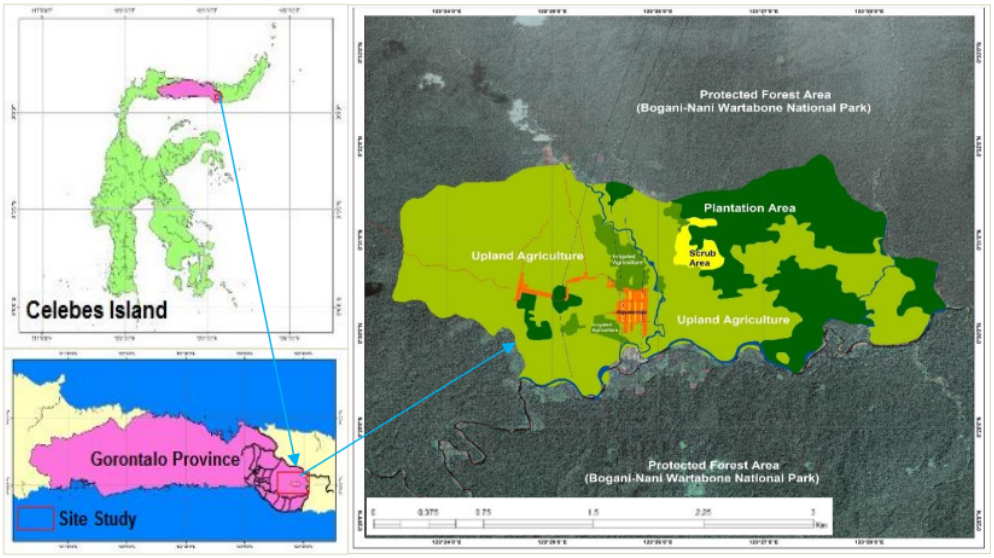

Figure 1. Research Location Map

Soil Survey and Land Observation

A set of soil survey tools, including: soil knife, pH meter, meter, hoe, spade, machete, clinometer and F marker. Meanwhile, the materials used consist of: soil maps, geological maps, slope maps, landform maps, land use maps, maps 1 : 12,000 scale land unit, soil profile card, plastic bag, rubber band, label paper, climate data from the local BMKG station for 5 years (2015-2021) and soil samples for laboratory analysis. This field research uses a soil survey method on a scale of 1: 12,000 by observing the characteristics of the land in 13 land units. Furthermore, field observations were carried out to determine the characteristics of the land in the form of elevation and slope. After that, 1 kg of soil samples were taken for analysis in the laboratory.

Soil Laboratory Analysis

Soil samples were air-dried for 3 days, then sieved through a 2 mesh sieve. The analysis of selected soil properties based on research parameters refers to the soil analysis procedure according to Eviyati & Sulaeman (2009). Soil reaction parameters (pH H_2O) were determined with a pH meter extracted in a solution of 1:2.5 soil and water. Organic carbon content using the Walkley and Black method. The P content was available using the Olsen method, while the cation exchange capacity (CEC) was extracted with 1N NH_4OAc pH 7.0 (ammonium acetate) on a dry sample of 105°C, while base saturation was determined by calculation. All soil data and selected land characteristic data are input in dbf or xls format.

Land Suitability Assesment

The deskwork in the suitability assessment is carried out based on the parameters of the selected land characteristics which are the same between the limiting factor method and the parametric method. Assessment of land suitability classes using the limiting factor method follows the land evaluation framework according to FAO (1976) from the order and class categories (suitable, not suitable) to units. Furthermore, the data on land characteristics and quality were compared with the selected Liberika Coffee land suitability criteria (Table 1) according to the Ditjendbun (2014), in order to obtain the actual land suitability class along with the limiting factors for land use. The limiting factor is then improved, so that the potential land suitability class is obtained.

Table 1. Selected Land Suitability Criteria for Liberica Coffee

Land use requirements /land characteristics	Land suitability class			
	S1	S2	S3	N
Elevation-el (m sl)	300 – 500	600 – 800; 0 – 300	800 – 1.000	>1,000
Slopes-sl (%)	0 – 8	8 – 25	25 – 45	>45
Nutrient retention (nr):				
Soil pH	5.5 – 6.0	6.1 – 7.0	7.1 – 8.0	>8.0
C-organic (%)	2 – 5	1 – 2; 5 – 10	0.5 – 1.0; 10 – 15	<0.5; >15
Cation exchange capacity (cmol)	>15	10 – 15	5 – 10	<5
Base saturation (%)	>35	20-35	<20	
Nutrient availability (na):				
Availability of P (ppm)	>16	10 – 15	<10	

Remark: (Ditjendbun, 2014), modifed.

Meanwhile, in assessing land suitability using the parametric method, it is estimated that the profitability of coffee uses several equations (Simbolon, 2018) based on the parameters of the selected soil and land properties, namely: Y = -2.672+0.026X (elevation), Y = 17,190-0.090X (slope), Y = 3.055+0.005X (soil pH), Y = 4.050-0.019X (C-organic), Y = -28.796+0.621X (P availability), Y = 32.450-0.109X (CEC), and Y = 0.457-0.002X (base saturation). In this case, Y = estimated production (tonnes/ha), X = soil and land properties parameters, CEC = cation exchange capacity, and KB = base saturation. The assumption of optimal profitability of liberica coffee used is 0.75 tons ha^{-1} (Martono, 2018). In order to assess the accuracy of the estimated profitability of the liberica coffee, it was analyzed using the Root Mean Square Error (RMSE) with the following equation:

$$RMSE = \sqrt{\frac{\sum_{t-1}^{n}(At - Ft)^2}{n}}$$

where: RMSE = root mean square error, At = actual profitability (ton ha^{-1}), Ft = estimated profitability (ton ha^{-1}), and n = number of data. The smaller or closer to 0 the value of the RMSE, the more accurate the prediction results will be. Furthermore, land suitability assessment for liberica coffee uses a land index of root mean square (Khiddir, 1986), namely:

$$LI = LC_{min}\sqrt{\frac{A}{100}\ x\ \frac{B}{100}\ x\ \frac{C}{100}\ x \ldots x\ \frac{N}{100}}$$

where: LI = land index; LC_{min} = minimum LC rating; A, B, C, ..., N = other LC in beside the minimum LC. Determination of land suitability classification based on LI is calculated from all LC which is influenced by the profitability of liberica coffee and has a certain land suitability class. LI score criteria using LI value criteria (Sys et al., 1991), namely: S1 class (very suitable) with a value of 75 – 100, S2 class (moderately suitable) with a value of 50 – 75, S3 class (marginally suitable) with a value of 25 – 50, and class N (not suitable) with value 0 – 25. All data and information obtained are described and presented in tabular form, while their spacial distribution is presented in map form.

RESULTS

Land Suitability Based on Limiting Factor Method

The result of matching the land suitability criteria with the land characteristics resulted in the actual land suitability class for liberica coffee in Pinogu Plateau (Table 2). It seems that the actual land suitability class was moderately suitable (S2) which was more dominant in an area of 2,149.64 ha or 76.66% compared to the marginally suitable class (S3) which was only 654.64 ha or only 23.34%. While the very suitable class (S1) and not suitable (N) has not found in the results of this assessment. The most dominant limiting factors in almost all LMUs for liberica coffee land use in the Pinogu Plateau include: nutrient retention (C-organic, base saturation and soil pH) and nutrients availability (P availability). In addition, there was an elevation limiting factor at LMU 1 and LMU 7.

Table 2. The Actual Land Suitability Class for Liberica Coffee in Pinogu Plateau

LMU	Elevation		Slope		pH		C-Organic		CEC		BS		Ava-P		Actual LSC	Area	
	LC (m sl)	LSC	LC (%)	LSC	LC	LSC	LC (%)	LSC	LC (cmol)	LSC	LC (%)	LSC	LC (ppm)	LSC		ha	%
1	293	S2el	3	S1	5.82	S1	1.59	S2nr	19.24	S1	32.75	S2nr	13.87	S2na	S2el,nr,na	70.81	2.53
2	307	S1	3	S1	5.88	S1	1.30	S2nr	23.77	S1	33.75	S2nr	15.85	S2na	S2nr,na	250.95	8.95
3	313	S1	3	S1	6.22	S2nr	0.78	S3nr	27.60	S1	28.00	S2nr	9.77	S3na	S3nr,na	36.34	1.30
4	302	S1	3	S1	5.64	S1	1.21	S2nr	22.77	S1	24.67	S2nr	12.22	S2na	S2nr,na	36.97	1.32
5	311	S1	3	S1	5.78	S1	1.46	S2nr	26.39	S1	29.25	S2nr	17.04	S1	S2nr	849.26	30.28
6	305	S1	3	S1	6.12	S2nr	1.02	S2nr	33.50	S1	29.68	S2nr	18.52	S1	S2nr	3.74	0.13
7	290	S2el	3	S1	6.28	S2nr	1.43	S2nr	27.92	S1	39.75	S1	14.53	S2na	S2el,nr,na	98.53	3.51
8	288	S1	3	S1	5.89	S1	1.92	S2nr	23.22	S1	36.67	S1	20.35	S1	S2nr	112.84	4.02
9	338	S1	3	S1	6.25	S2nr	1.79	S2nr	27.10	S1	37.00	S1	14.98	S2na	S2nr,na	305.44	10.89
10	300	S1	8	S1	5.92	S1	1.38	S2nr	23.67	S1	42.33	S1	9.98	S3na	S3na	452.57	16.14
11	334	S1	3	S1	5.96	S1	1.15	S2nr	27.69	S1	33.00	S2nr	17.12	S1	S2nr	369.42	13.17
12	306	S1	8	S1	5.95	S1	1.07	S2nr	25.03	S1	39.50	S1	16.41	S1	S2nr	51.68	1.84
13	310	S1	3	S1	6.00	S1	1.35	S2nr	32.67	S1	23.67	S2nr	7.78	S3na	S3na	165.73	5.91
Area (ha)																2,804.28	100

Remark: LMU = land mapping unit, LC = land characteristic, LSC = land suitability class, CEC = cation axchange capacity, BS = base saturation, Ava-P = P availability, m sl = mean sea level, ppm = part per million.

After making efforts to improve the actual land suitability class against the limiting factor, all LMUs can be upgraded to potential land suitability class, except for LMU 1 and LMU 7 which cannot be repaired because of the elevation limiting factor (Table 3). The limiting factors for nutrient retention, both pH, C-organic, and low base saturation were corrected with the addition of organic matter, while the

limiting factor for available nutrients in the form of low P availability was corrected with the addition of P fertilizer. The most dominant potential land suitability class was very suitable (S1) covering an area of 1,980.30 ha or 70.62% and the rest including S2 class covering an area of 823.98 ha or 29.38% only.

Table 3. Potential Land Suitability Classes for Liberica Coffee in Pinogu Plateau

LMU	Actual LSC	Limiting Factors	Efforts	Potential LSC	Area	
					ha	%
1, 7	S2el,nr,na	Elevation, nutrient retention (C-organic, base saturation), nutrient availability (available of P)	Can not be fixed (elevation)	S2	169,34	2.53
2, 4, 9	S2nr,na	Nutrient retention (C-organic, base saturation, pH), nutrient availability (available of P)	- Addition of organic material - Addition of P fertilizer	S1	593,36	8.95
3	S3nr,na	Nutrient retention (C-organic), nutrient availability (available of P)	- Addition of organic material - Addition of P fertilizer	S2	36,34	1.30
5, 6, 8, 11, 12	S2nr	Nutrient retention (C-organic, base saturation)	- Addition of organic material	S1	1.386,94	30.28
10, 13	S3na	Nutrient availability (available of P)	- Addition of P fertilizer	S2	618,30	16.14
Luas (Ha)					2.804,28	100

Remark: LMU = land mapping unit, LSC = land suitability class.

Land Suitability Based on Parametric Method

The results of the profitability analysis (productivity) of liberica coffee based on each land characteristic showed that the highest profitability was obtained on the slope characteristics which averaged 1.69 tons ha^{-1}, while the lowest profitability was obtained on the available P characteristics which only ranged from 0.16 – 0.24 ton ha^{-1} with an average of 0.20 ton ha^{-1} (Table 4). The remaining land characteristics has an average profitability 0.30. The results of the RMSE analysis on the alleged profitability of liberica coffee were all close to 0, but LMU 3, 10,12 and LMU 13 are smaller (0.51) compared to LMU 8 which is the highest (0.53). The remaining LMUs has an RMSE value of 0.52 (Table 4). The profitability of liberica coffee will affect the land characteristic index which will ultimately determine the land index and land suitability class for liberica coffee.

It seems that the relative land characteristic index values follow the pattern of profitability for liberica coffee in the Pinogu Plateau. The highest land characteristic index value and reaching the optimal value was the slope characteristic which averaged a value of 100 (Table 5), while the lowest land characteristic index value was obtained for the available P which an average of P availability index of 26.39 only. The remaining land characteristics are relatively diverse but the average value of the land characteristic index was 30 in the remaining LMUs in the Pinogu Plateau. The land characteristic index value affects the land index value which results in LMU 3 and LMU 13 obtaining the highest land index, respectively 76 and 80. Meanwhile, the LMU 8 as the lowest land index value which was 50 only. The remaining LMUs get land index values ranged from 50 – 71.

Table 4. Estimated Value of Liberica Coffee Provitability in Pinogu Plateau

Characteristic /*Provitability*	LMU												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Elev. (m sl)	293	307	313	302	311	305	290	288	338	300	334	306	310
Y (ton ha^{-1})	*0.49*	*0.53*	*0.55*	*0.52*	*0.54*	*0.53*	*0.49*	*0.48*	*0.61*	*0.51*	*0.60*	*0.53*	*0.54*
Slo. (%)	3	3	3	3	3	3	3	3	3	8	3	8	3
Y (ton ha^{-1})	*1.69*	*1.69*	*1.69*	*1.69*	*1.69*	*1.69*	*1.69*	*1.69*	*1.69*	*1.65*	*1.69*	*1.65*	*1.69*
pH	5.82	5.88	6.22	5.64	5.78	6.12	6.28	5.89	6.25	5.92	5.96	5.95	6.00
Y (ton ha^{-1})	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*	*0.31*

Characteristic /*Provitability*	LMU 1	2	3	4	5	6	7	8	9	10	11	12	13
C-Org (%)	1.59	1.30	0.78	1.21	1.46	1.02	1.43	1.92	1.79	1.38	1.15	1.07	1.35
Y (ton ha^{-1})	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*	*0.40*
CEC (cmol)	19.24	23.77	27.60	22.77	26.39	29.68	27.92	23.22	27.10	23.67	27.69	25.03	32.67
Y (ton ha^{-1})	*0.30*	*0.30*	*0.29*	*0.30*	*0.30*	*0.29*	*0.29*	*0.30*	*0.29*	*0.30*	*0.29*	*0.30*	*0.29*
BS (%)	32.75	33.75	28.00	24.67	29.25	29.68	39.75	36.67	37.00	42.33	33.00	39.50	23.67
Y (ton ha^{-1})	*0.39*	*0.39*	*0.40*	*0.41*	*0.40*	*0.40*	*0.38*	*0.38*	*0.38*	*0.37*	*0.39*	*0.38*	*0.41*
Av-P (ppm)	13.87	15.85	9.77	12.22	17.04	18.52	14.53	20.35	14.98	9.98	17.12	16.41	7.78
Y (ton ha^{-1})	*0.20*	*0.19*	*0.23*	*0.21*	*0.18*	*0.17*	*0.20*	*0.16*	*0.19*	*0.23*	*0.18*	*0.19*	*0.24*
$\bar{Y}$ (ton ha^{-1})	*0.60*	*0.60*	*0.61*	*0.60*	*0.60*	*0.60*	*0.60*	*0.59*	*0.61*	*0.60*	*0.61*	*0.59*	*0.61*
Stdev	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.48	0.49	0.48	0.49
RMSE	0.52	0.52	0.51	0.52	0.52	0.52	0.52	0.53	0.52	0.51	0.52	0.51	0.51

Remark: LMU = land mapping unit, Elev. = elevation, Slo. = slopes, C-Org = C-organic, Exc. = exchangeable, CEC = cation axchange capacity, BS = base saturation, Ava-P = P availability, m sl = mean sea level, ppm = part per million, Stdev = standard deviation, RMSE = root mean square error.

Based on the value of the land index, the land suitability class for liberica coffee was more dominant S2 with covering an area of 2,489.37 ha or 88.77% (Table 5). Meanwhile, the S1 class was 202.07 ha or 7.21% and the S3 class was 112.84 ha or 4.02% only without not suitable class (N).

Table 5. Value of Land Characteristics Index, Land Index and Land Suitability Class for Liberica Coffee

Profitability /LC Value	LMU 1	2	3	4	5	6	7	8	9	10	11	12	13
Y-El. (ton ha^{-1})	0.49	0.53	0.55	0.52	0.54	0.53	0.49	0.48	0.61	0.51	0.60	0.53	0.54
LC-El.	65.95	70.80	72.88	69.07	72.19	70.11	64.91	64.21	81.55	68.37	80.16	70.45	71.84
Y-Sl. (ton ha^{-1})	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.65	1.69	1.65	1.69
LC-Slo.	100	100	100	100	100	100	100	100	100	100	100	100	100
Y-pH (ton ha^{-1})	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
LC-pH	41.12	41.13	41.15	41.11	41.12	41.14	41.15	41.13	41.15	41.13	41.13	41.13	41.13
Y-Corg. (ton ha^{-1})	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
LC-Corg.	53.60	53.67	53.80	53.69	53.63	53.74	53.64	53.51	53.55	53.65	53.71	53.73	53.66
Y-CEC (ton ha^{-1})	0.30	0.30	0.29	0.30	0.30	0.29	0.29	0.30	0.29	0.30	0.29	0.30	0.29
LC-CEC	40.47	39.81	39.26	39.96	39.43	38.95	39.21	39.89	39.33	39.83	39.24	39.63	38.52
Y-BS (ton ha^{-1})	0.39	0.39	0.40	0.41	0.40	0.40	0.38	0.38	0.38	0.37	0.39	0.38	0.41
LC-BS	52.20	51.93	53.47	54.36	53.13	53.02	50.33	51.16	51.07	49.64	52.13	50.40	54.62
Y-Ava.P (ton ha^{-1})	0.20	0.19	0.23	0.21	0.18	0.17	0.20	0.16	0.19	0.23	0.18	0.19	0.24
LC-Ava.P	26.91	25.27	30.31	28.28	24.29	23.06	26.37	21.54	25.99	30.13	24.22	24.81	31.95
LI	64	62	76	70	61	56	61	50	67	71	63	60	80
LSC	S2	S2	S1	S2	S2	S2	S2	S3	S2	S2	S2	S2	S1
Area (ha)	70.81	250.95	36.34	36.97	849.26	3.74	98.53	112.84	305.44	452.57	369.42	51.68	165.73
Area (%)	2.53	8.95	1.30	1.32	30.28	0.13	3.51	4.02	10.89	16.14	13.17	1.84	5.91

Remark: LMU = land mapping unit, Y = profitability, LC = land characteristic rating, Exc. = exchangeable, Ava. = availability, El. = elevation, Sl. = slope, Corg. = C-organic, K = potassium, Ca = calcium, Mg = magnesium, Na = natrium, P = phosfor, CEC = cation exchange capacity, BS = base saturatio, LI = land index, LSC = land suitability classes.

Comparison of Land Suitability Classes and Their Impact on Land Management

Based on the results of the land suitability assessment using the limiting factor method and the parametric method, there were similarities in land suitability class (S2 = S2) covering an area of 621.91 ha or 22.18% at LMU 1, 7 and LMU 10 with (Table 6). While the difference in results between the two methods follows a pattern: S1 ≠ S2 covering 1,867.46 ha or 66.59% at LMU 2, 4, 5, 6, 9, 11, and LMU 12, S2 ≠ S1 pattern covering an area of 202.07 ha or 7.21% at LMU 3 and LMU 13, while the S1 ≠ S3 pattern was only 112.84 ha or 4.02% at LMU 8.

Table 6. Comparison of Land Suitability Classes with Limiting Factors and Parametric Methods for Liberica Coffee in Pinogu Plateau

LMU	Land Suitability Class		Area	
	Limiting Factor Method	Parametric Method	ha	%
1, 7, 10	S2	S2	621.91	22.18
2, 4, 5, 6, 9, 11, 12	S1	S2	1,867.46	66.59
3, 13	S2	S1	202.07	7.21
8	S1	S3	112.84	4.02
	Area (ha)		2,804.28	100.00

Remark: LMU = land mapping unit.

DISCUSSION

The level of land suitability for a particular use, both in actual and after repair or potential conditions, was known as land suitability (Ritung et al., 2011), where the results become the basis for developing a land use on a large scales (Hardjowigeno & Widiatmaka, 2007). In land suitability assessment for liberica coffee using the limiting factor method on the actual land suitability class, it turned out that the S2 class was more dominant with the limiting factors of elevation, nutrient retention (C-organic, base saturation and soil pH) and available nutrients (availability of P). All of these limiting factors can be improved, except for the elevation limiting factor which according to Hardjowigeno & Widiatmaka (2007) cannot be improved. The ideal elevation for Liberica coffee is between 300 – 500 m above sea level (Ditjendbun, 2014). Land suitability class S3 has limiting factors for nutrient retention (C-organic) and available nutrients (availability of P). The limiting factors for nutrient retention (C-organic, base saturation and soil pH) can be improved by adding organic matter (Suheri et al., 2018) because it can increase soil pH and C-organic (Afandi et al., 2015; Siregar et al., 2017), and base saturation (Sembiring et al., 2015). While the availability of nutrients (available P) can be improved by applying fertilizers (Suheri et al., 2018), especially P fertilizers. According to Singh et al., (2003) and Mahapatra et al., (2019), land management can be done by adding organic matter and fertilization according to the recommended dose of fertilizer. Land management factors play a very important role in maintaining soil organic matter content (Dariah et al., 2005). Meanwhile, according to (Suheri et al., 2018), fertilization is intended to add nutrients to the soil for plants.

The improvement of the actual suitability class was able to increase the liberica coffee class in Pinogu Plateau to a potential land suitability whose assessment results were dominant in the S1 class compared to S2, without the S3 class and the N class with the class S1 > S2 pattern, so that the area and distribution of these classes also increased. This is in line with the statement (Refitri et al., 2016) that land that has a suitability class of S3 has the opportunity to be improved through various land improvement efforts, so that it becomes class S2 to class S1. However, the land suitability class assessment using the limiting factor method has not at all linked the class acquisition to the profitability of liberica coffee itself, so that there is often a contrast between the land suitability class and its real profitability. In fact, at LMU 4 and LMU 6, the existing land use conditions are irrigated rice fields, rainfed rice fields and swamps that are often flooded, so the actual land suitability class S2 and potential land suitability class S1 for liberica coffee still need to be checked again in the field.

In principle, the parametric method in evaluating land suitability is to assign values to different limiting levels of land properties, on a normal scale given a maximum value of 100 to a minimum value of 0 (Juita et al., 2020). In land suitability assessment for liberica coffee in Pinogu Plateau with parametric

method dominated by S2 class followed by S1 class and S3 class without class N with class pattern S2 > S1 > S3. It seems that the land index obtained by the parametric method is closer to the real conditions in the field, where the average production of liberica coffee in the Pinogu Plateau ranges from 0.51 to 0.61 tons ha^{-1}, while the profitability of Pinogu coffee currently reaches 0.75. ton ha-1 (Martono, 2018). This parametric method with the square root of the land index uses a minimum rating to assess land suitability classes (Juita et al., 2020), so that the minimum rating in this case the low availability of P nutrients causes the low land suitability class. A low land suitability index should be improved so that the plant grows optimally (Israminanti et al., 2020). Low nutrient availability can be corrected by applying fertilizers (Suheri et al., 2018), especially P.

The difference in land suitability class between the two methods has an impact on land management for liberica coffee in Pinogu Plateau. In the limiting factor method, differences in land suitability classes were caused by prominent limiting factors (Table 3) including: elevation, nutrient retention (pH, organic C, base saturation), and nutrient availability (available P). This condition resulted in more land management inputs needed, including the addition of organic matter and P fertilization. Meanwhile, the difference in land suitability classes in the parametric method was caused by the interaction of all soil and land properties parameters with the profitability of liberica coffee in Pinogu Plateau (Table 5), although the levels of The available P yields the lowest profitability and the slope with the highest profitability. Thus, the low availability of P nutrients can be corrected by only P fertilization, resulting in fewer inputs for land management.

This research uses both land suitability assessment methods to be the same and consistent in terms of the type and number of land characteristics used, so that differences in land suitability assessment results are not caused by differences in land characteristics. but because of the final value produced by both methods. In addition, the use of land characteristics is also based on the availability of mathematical equations to estimate the profitability of liberica coffee because only LMU 3, 9, 10 and LMU 13 have liberica coffee plants and have produced 0.75 tons ha^{-1} (Martono, 2018). Meanwhile, other LMUs do not have liberica coffee plants, so the profitability must be estimated.

Limitations in the type and number of land characteristics used in this study are a challenge for future research to be added or expanded to other land characteristics. This refers to the land suitability criteria for liberica coffee (Ditjendbun, 2014), where the characteristics of land that have not been used in this study are: annual rainfall, dry month length, effective depth, texture, rock on the surface, inundation, drainage class, nitrogen (N), salinity and aluminum saturation (Al). However, the results of this study have shown that the use of the parametric method is more sensitive to the increase or decrease in the profitability of liberica coffee and better describes the real conditions in the field. Meanwhile, the use of the limiting factor method, although the land suitability class for liberica coffee is higher, is in contrast to the facts on the ground, so it must be re-checked.

Research on land suitability for liberica coffee in Pinogu Plateau is the first research conducted in this area and in the province of Gorontalo. Therefore, Liberika coffee, which is endemic to the Pinogu Plateau, Bone Bolango Regency, Gorontalo Province, needs to be maintained in the future. In addition to the Pinogu area, liberica coffee is also found in the Modayag District, East Bolaang Mongondow Regency, North Sulawesi Province, which is still an island of Sulawesi and was endemic in the province, so that future research is interesting and can be focused on comparing land suitability classes for liberica coffee in the two regions and their agronomic performance and profitability.

CONCLUSION

The actual of land suitability class for liberica coffee using the limiting factor method consists of moderately suitable class (S2) and a marginally suitable class (S3) with elevation, nutrient retention and nutrient availability constraints. Efforts to improve the class by adding organic matter and fertilization, so the potential class were very suitable class (S1) and S2 class. The parametric method consists of S1, S2 and S3 class. The input for land management using the parametric method was P fertilization only.

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STATEMENT OF COMPETING INTEREST

The authors state that no competing financial or personal interests might arise and affect the work reported in this paper.

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