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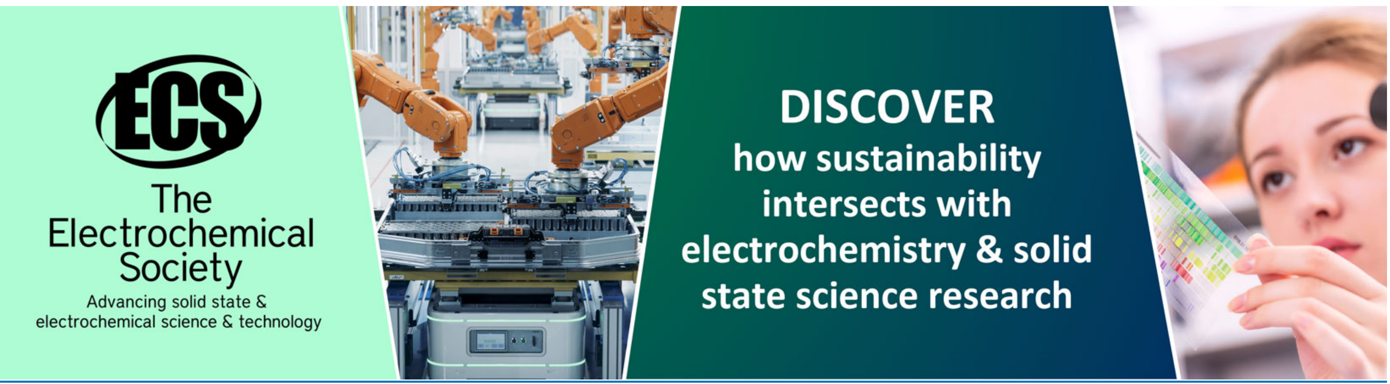

Analysis of land productivity based on soil fertility in cocoa plantation land in Campalagian district, Polewali Mandar Regency

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Abstract. Potential areas for developing certain commodities can be determined by using the index value of land productivity. This study aims to analyze the land productivity of Campalagian District based on soil fertility level for the development of cocoa plants. The quantitative research method uses the Storie equation in determining the value of the land productivity index. Determination of observation points based on purposive sampling method. Soil properties determined in the field and the laboratory, including slope, effective depth, texture, pH, C-Organic, N-Total, P_2O_5, CEC, and the number of interchangeable bases. The results of the analysis of the land productivity index of the Campalagian district are classified as bad to good, with land productivity index values ranging from 13.89 to 51.37, with limiting factors, namely slope, effective depth, texture, C-Organic, and N-Total.

1. Introduction

Campalagian district has an area of 11,755 hectares of the total area of Polewali Mandar Regency. Campalagian district is divided into 18 villages or sub-districts. The agricultural sector is still the main aspect to be developed in the region because it is the source of most of the population's livelihood. Cocoa is the second largest commodity after coconut. The average area of cocoa plantations in the last eight years (2010-2017) was 2,823.04 Ha with a production of 1,152.28 tons [1].

In cocoa cultivation, it is the type of cultivar that must be considered and the high soil fertility in the land to keep nutrient needs for the commodity to be developed and cultivated. Soil factor is one of the determining factors in determining the cocoa plant's productivity because soil provides nutrients for the plant and is a determining factor for soil fertility. Cocoa plants need fertile soil that has a high nutrient (chemical) composition. However, the problems that arise over time, apart from the age of the plants that are getting older, affect productivity, but some factors decrease soil fertility [2].

The cocoa productivity produced in the region is still low to medium, with an average annual yield of only 420.87 kg/ha/year. Meanwhile, the desired optimal yield for smallholder cocoa plantations or scale farmers according to [3] in the amount of 800-1,500 kg/ha/year. It indicates that the cocoa productivity obtained is not in accordance with the desired optimal results. Productivity is not optimal, can be affected by soil fertility in the area. Therefore, to estimate the potential fertility in a land, it can be determined by calculating the land productivity index. It can be done using various methods, one of which is often used, namely land evaluation according to [4] with a parametric system, then modified by [5] through the productivity index formula equation.

2. Methods

The research was carried in the Campalagian district, Polewali Mandar regency, West Sulawesi. Soil sample analysis was carried out at the Laboratory of Chemistry and Soil Fertility, Faculty of Agriculture, Hasanuddin University, Makassar. This research had been carried out from December 2019 to June 2020.

The tools used in this research are GPS (Global Position System), software ArcGIS 10.3, meter bar, Camera, ring sample, board, hummer, cutter, crowbar, hoe, plastic sample, stationery, and a set of tools for soil analysis in the laboratory. The materials used are disturbed soil samples and undisturbed soil samples, data RTRW Polewali Mandar regency, administrative map, slope map, soil type map, soil profile worksheet, and soil analysis materials laboratory.

This research uses a purposive sampling method of soil sampling based on where cocoa gardens are considered representative. Laboratory analysis was then carried out to determine soil productivity in terms of its physical and chemical properties, then entered into the productivity index equation formula through the [5] approach modified according to research needs using weighting (1-100). The working map of soil sampling can be seen on the figure 1.

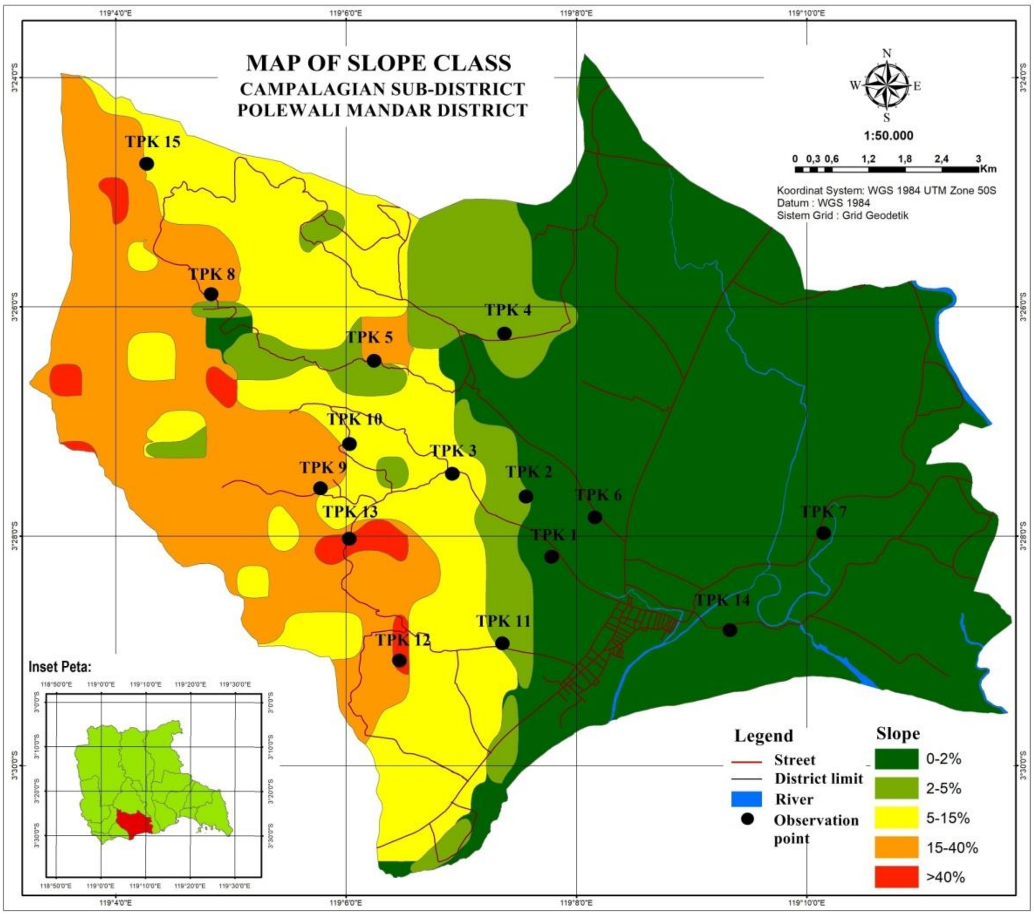

Figure 1. Working map of soil sampling.

Table 1. Parameter and soil analysis methods in the laboratory.

Parameter	Method
Soil physical	
Texture	Hydrometer
Soil depth	Soil profile
Soil chemical	
pH H_2O	pH Meter
C-Organic	Walkey and Black
N-Total	Kjeldahl
P_2O_5	Olsen
CEC, Ca, Mg, K	Titration

The basic model for calculating the productivity index in this study uses [5] method as follows:

$$IP = A \,.\, B \,.\, C \,.\, X \tag{1}$$

note :
IP = Produktivity index
A = Soil profile characteristic factors
B = Soil texture factor
C = Slope factor.
X = Other factors that are modified.

The formula above is then adjusted to the research needs so that the procedure used is as follows:

$$IP = \sum_i^n \left(\frac{T}{100} \times \frac{B}{100} \times \left(\frac{H}{100} \times \frac{P}{100} \times \frac{N}{100} \times \frac{K}{100} \times \frac{J}{100} \times \frac{C}{100}\right)\right) \times 100 \tag{2}$$

note: T = Texture; B = Effective depth; H = Soil pH; P = P2O5; N = Nitrogen; K = Apparent CEC; C = C-Organic; J = Sum of basic cations.

Table 2. Productivity class (P).

P	Class	Score
1	Very good	100-65
2	Good	64-35
3	Moderate	34-20
4	Poor	19-8
5	Very poor	7-0

Source: [3]

3. Results and discussions

3.1. Climatic characteristics

3.1.1. Annual precipitation. Based on annual precipitate data for the last five years (2013-2017), the yearly precipitate in Campalagian District is 2031 mm/year. According to Schmidt Ferguson, it is classified as climate type B (wet) with eight wet months and three dry months.

3.1.2. Temperature. Based on data for the last five years (2015-2019), the research area has an average temperature of 27.86 °C, a minimum temperature of 26.98 °C, and a maximum temperature of 28.32 °C. According to [3], the temperature in this area is very suitable for the growth of cocoa plants. The ideal temperature for growing cocoa plants ranges from 26 °C - 28 °C.

3.1.3. Humidity. Based on data for the last five years (2015-2019), the research area has a humidity of 78.07%. According to [3] stated that the humidity in this area is very suitable for the growing requirements for cocoa plants. The ideal humidity for cocoa plants is 55-45%.

3.2. Actual productivity index

The land productivity index for cocoa plant development in the Campalagian district is classified as good (P2), moderate (P3), poor (P4) with slope limiting factors, effective depth, soil texture, C-Organic, and Nitrogen. Based on interviews with farmers, the average cocoa production obtained in the area is less than 1 ton/ha/year. The production range starts from 0.1 ton/ha/year to 0.5 ton/ha/year. These results are not in accordance with the optimum results desired for cocoa plantations according to [3], which is 0.8-1.5 ton/ha/year. Low production is also indicated by the appearance of the plants at the time of the survey, namely: irregular spacing, the average condition of the plants is quite dense, many turning branches, protected branches, branches that enter deep into the adjacent plant canopy so that they can block sunlight, which reaches the leaves and can inhibit the photosynthetic process of plants. At several points, the land productivity index does not have a significant correlation with the yield obtained. The plant management supports are carried out and can be seen in tables 3 and 4.

Table 3. Dignity scale, index, and productivity class for cocoa plantations.

Observation Point		Land Characteristics								IP	Productivity (P)
		T	B	H	P	N	K	J	C		
1	S	C<60s	100	6.05	11.55	0.12	56.93	11.82	1.14		
	W	100	95	88	86	65	100	100	72	33.60	3
2	S	C<60s	90	6.36	16.04	0.15	69.51	10.44	1.01		
	W	100	75	99	100	73	100	100	67	36.30	2
3	S	C<60s	90	6.98	18.04	0.10	63.52	10.19	1.21		
	W	100	75	86	100	60	100	100	74	28.65	3
4	S	CL	35	7.01	19.88	0.11	62.01	8.38	1.16		
	W	100	36	85	100	63	100	100	73	13.89	4
5	S	SiCs	70	6.47	13.69	0.13	36.73	9.65	1.17		
	W	100	56	98	92	68	100	100	73	24.89	3
6	S	CL	135	6.86	16.70	0.13	69.40	14.33	1.36		
	W	100	100	89	100	68	100	100	80	47.77	2
7	S	SiCL	90	6.39	13.09	0.16	75.14	12.50	1.41		
	W	100	75	100	90	76	100	100	82	41,98	2
8	S	C<60s	70	6.09	16.77	0.26	48.35	15.27	1.46		
	W	100	56	90	100	87	100	100	84	36.39	2
9	S	C<60s	95	5.81	16.61	0.29	48.29	9.79	1.62		
	W	100	80	76	100	88	100	100	86	45.78	2
10	S	C>60s	70	6.91	20.31	0.26	32.48	11.52	1.39		
	W	95	56	87	100	87	100	100	81	32.59	3
11	S	SiCL	50	7.16	20.45	0.26	59.48	10.22	1.47		
	W	100	40	78	100	87	100	100	84	22.84	3
12	S	SiCs	25	7.07	22.03	0.18	52.13	13.89	1.51		
	W	100	33	82	100	80	100	100	85	18.17	4
13	S	SiCs	90	6.59	22.94	0.23	40.61	11.85	1.47		
	W	100	75	95	100	86	100	100	84	51.37	2
14	S	SL	80	6.76	14.07	0.21	142.81	9.34	1.39		
	W	60	65	91	93	85	100	100	81	22.71	3
15	S	C<60s	50	7.21	19.58	0.25	65.17	11.08	0.71		
	W	100	40	76	100	86	100	100	58	15.23	4

Note: S = Score; W = Weight; T = Texture; B = Effective depth; H = Soil pH; P = P_2O_5; N = Nitrogen; K = Apparent CEC; C = C-Organic; J = Sum of basic cations

Tabel 4. Land productivity index, class, and limiting factors.

Observation Point	IP	Productivity Class	Limiting Factor
1	33.60	Moderate	Nitrogen
2	36.30	Good	C-Organic
3	28.65	Moderate	Nitrogen
4	13.89	Poor	Effective depth
5	24.89	Moderate	Slope
6	47.77	Good	Nitrogen
7	41.98	Good	Effective depth
8	36.39	Good	Slope
9	45.78	Good	Slope
10	32.59	Moderate	Effective depth
11	22.84	Moderate	Effective depth
12	18.17	Poor	Effective depth, Slope
13	51.37	Good	Slope
14	22.71	Moderate	Texture
15	15.23	Poor	Effective depth

3.3. Land improvement action

Land can be utilized optimally and sustainably if improvements are made in accordance with the limiting factors found at each observation point. The method that needs to be done in the improvement effort is paying attention to the land's characteristics and quality. The limiting factors that exist when efforts are made to improve it, the current land productivity index can be further increased, affect the production of the resulting crop.

Efforts are being made to overcome the slopes' limiting factor by making the terraces of mounds equipped with water channels, cutting slopes to prevent erosion, or shortening the slope to the slope [6]. The mounds created can be planted with cover crops such as legume crops. This is consistent with the research results of [7] stated that the planting of soybean and Mucuna bracteata resulted in a fairly large land cover. About 75% of the soil surface was evenly covered with more variety of soil surface roughness conditions due to plant roots.

The limiting factor for the effective depth of roots can be overcome by combining existing plants with plants that are not deep-rooted and play a role in producing more biomass such as legumes (*Gliricidia sepium*) and other cover crops. According to [6], crop selection is adjusted to farmers' needs and economic values, such as bean types. Gamal (*Gliricidia sepium*) is a shade plant suitable for cocoa plants. Meanwhile, the limiting factor for soil texture, in general, cannot be improved, so it is the heaviest factor at TP 14.

C-Organic nutrient deficiency (chemistry) can be overcome with sufficient organic matter. The addition of green manure, plant residues, and manure has a significant effect on soil organic C content. Based on [8] research, manure from chicken manure 20 tonnes/ha can increase organic C-0.43% value. According to [9], efforts to increase organic matter levels can also be done by utilizing litter from pruning and immersion of cocoa pods. Cocoa pod skin contains 900 kg/ha of organic substances. The leaves of shade plants, such as gliricidia, are also capable of adding nutrients. A total of 1,990 kg / ha / year of fallen gliricidia leaves gave nitrogen nutrients of 40.8 kg / ha, phosphorus 1.6 kg / ha, potassium 25 kg / ha, and magnesium 9.1 kg / ha.

Efforts to increase nitrogen nutrients can be done by planting legume plants which are expected to anchor nitrogen and C-Organic elements. According to [10], Gamal (*Gliricidia sepium*) is a tree legume plant that can adapt to all types of soil, is dry resistant, and always produces forage in the dry season is defoliated regularly. Gamal plants are used as hedges and can support soil fertility through nitrogen fixation (N2). According to [11], increasing the element N can be done by planting *Mucuna bracteata*. *Mucuna bracteata* is one of the LCC (Legume Cover Crop) plants as a tolerant plant and can grow well in various soil types. *Mucuna bracteata* is capable of producing high biomass and contains higher N than other ground cover crops.

4. Conclusions

The land productivity of the Campalagian district for cocoa plant development is classified as poor to good, with a productivity index ranging from 13.89 to 51.37. Soil fertility factors that limit cocoa productivity in the District of Campalagian include C-Organic and Nitrogen, while physical factors that determine include slopes, effective depth, and texture.

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