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Land suitability evaluation for cocoa using a parametric approach in West Sulawesi

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Abstract. Cocoa is the main plantation crop in Indonesia after rubber and oil palm. Indonesia's cocoa production is the sixth-largest after Ghana and Ivory Coast. Cocoa cultivation spreads to almost all islands in Indonesia. However, the largest is on the island of Sulawesi. West Sulawesi is one of the largest cocoa producers in Indonesia. The decline in cocoa production has continued since 2012. One of the causes of the decline in cocoa production is a decrease in acreage and low productivity of the cocoa plant. The current average cocoa productivity is only 797 kg/ha/year. This productivity is very low compared to the optimum productivity, reaching 2,000-3,000 kg/ha/year. One of the causes of low productivity is uneven land suitability. Cocoa is grown on land with a poor land index. This study aims to study the land index in West Sulawesi to develop land suitability for cocoa plants. His research took place in January-August 2020. The collection of representative points consisted of 30 points spread over four districts in West Sulawesi, namely Polewali Mandar, Majene, Mamuju and Mamasa Regencies. The results showed that there was a strong correlation between land index values and cocoa productivity. Each increase in the land index will increase the productivity of specific cocoa plants for the West Sulawesi Region. The highest Land Suitability Index value (53.56) was obtained on land with cocoa productivity of 2,000 kg /ha/year. The lowest Land Suitability Index value is obtained on land with a 700 kg/ha/year productivity.

1. Introduction

Cocoa is the main plantation crop in Indonesia after rubber and oil palm. Indonesia's cocoa production is the sixth-largest after Ghana, Ivory Coast, Ecuador, Cameroon and Nigeria. Cocoa cultivation spreads to almost all islands in Indonesia. However, the largest cocoa production is on the island of Sulawesi. West Sulawesi is one of the cocoa production centres in Sulawesi. The area of cocoa planted in West Sulawesi in 2018 was 138,606 hectares with a total production of 57,650 tons. Cocoa production has continued to decline since 2012. One of the causes of the decline in cocoa production is a decrease in acreage and low productivity of cocoa. The average cocoa productivity is only 797 kg /ha/year. The optimum productivity of cocoa can reach 2,000-3,000 kg /ha/year [1]. One of the causes of low cocoa productivity is improper land suitability. Selection of a suitable land requires a more actual land suitability evaluation method. One of them is to evaluate the area-specific land suitability index [2]. The suitability of land for plants affects the productivity of plants, including cocoa [3, 4, 5]. Soil chemical requirements for cocoa plants include cation exchange capacity, exchangeable bases, pH H₂O, salinity,



base saturation and Organic carbon [6]. The results of land suitability evaluation for cocoa plants can be used as a consideration in developing and increasing specific cocoa productivity in West Sulawesi.

2. Materials and methods

Research on the effect of land suitability evaluation for cocoa in west Sulawesi using the parametric approach used quantitative methods with a deductive approach. This research took place from July-August 2019 in 4 districts in West Sulawesi Province. The selection of research locations was based on existing cocoa production data in West Sulawesi Province. The map of the land system obtained by the largest harvested and production areas are Polewali Mandar, Majene, Mamuju and Mamasa Regencies. The determination of the 30 point representative profiles was based on productivity data and cocoa cultivation techniques (figure 1). Representative points were determined at locations that had homogeneous clone and culture techniques. Furthermore, the soil samples were analyzed at the Hasanuddin University Soil Fertility Laboratory. The land suitability index was obtained using a method with equations [7]:

$$LSI = A \times \frac{B}{100} \times \frac{C}{100} \times \dots \quad (1)$$

notes:

LSI = Land suitability index

A, B, C, D = the weight of each characteristic.

3. Results and discussion

3.1. Climatic characteristics

Based on the West Sulawesi Meteorology and Geophysics Agency (BMKG) data, the annual rainfall in the four districts tends to be the same. Rainfall data for 15 years (2005-2019) shows that Mamasa Regency as an area has the highest rainfall compared to Majene, Mamuju and Polewali Mandar Regencies. The annual rainfall distribution map is presented in figure 1.

The air temperature at the research location shows that Mamasa Regency has an air temperature lower than the air temperature in other districts. In general, Mamasa Regency is classified as a wet tropical climate with an average annual temperature of 23.17 °C with a minimum temperature of 18.22 °C and an average maximum temperature of 23.17 °C. The highest cocoa productivity was obtained at locations with an average annual temperature of 25.22 °C and a maximum temperature of 28.63 °C. The highest cocoa productivity was found in Patampanua Village, Matakali district, Polewali Mandar regency. The average relative humidity for Polewali Mandar regency ranges from 83.03%, Majene 79.21%, Mamasa 85.91%, Mamuju 75.80%. The highest average humidity is located in Mamasa Regency, 85.91%. Consecutively Polewali Mandar (83.03%), Majene (79.21%), and the lowest were in Mamuju Regency, 75.80%.

3.2. Soil characteristics

The soil analysis results show that the soil with the highest Cation Exchange Capacity (CEC) is in Mamuju Regency, which is 33.17 cmol (+) kg⁻¹. The lowest CEC value was found in Landi Kanusuang Village, Mapilli district, Polewali Mandar Regency, with a CEC value of 7.56 cmol (+) kg⁻¹.

The soil analysis results showed that the number of exchangeable bases (Ca + Mg + K + Na) varied for the study location. The number of bases in Polewali Mandar Regency ranges from 4.16 - 10.95 cmol (+) kg⁻¹, Majene ranges from 5.46 - 7.47 cmol (+) kg⁻¹, Mamasa ranges from 10.55– 13.78 cmol (+) kg⁻¹ and Mamuju district ranged from 12.57-13.3 cmol (+) kg⁻¹. The characteristic number of bases that can be exchanged shows the number of cations or nutrients available to plants. The lowest amount of exchangeable base cations was found in the Induk Makkombong Village, Matakali District, Polewali Mandar Regency of 4.16 cmol (+) kg⁻¹ with a cocoa plant productivity level of 2,000 kg/ha/year (high category). Meanwhile, the highest number of exchanges was found in Masoso village, Bambang district,

Mamasa Regency, amounting to 13.78 cmol (+) kg⁻¹ with cocoa productivity of 2,000 kg/ha/year (high category).

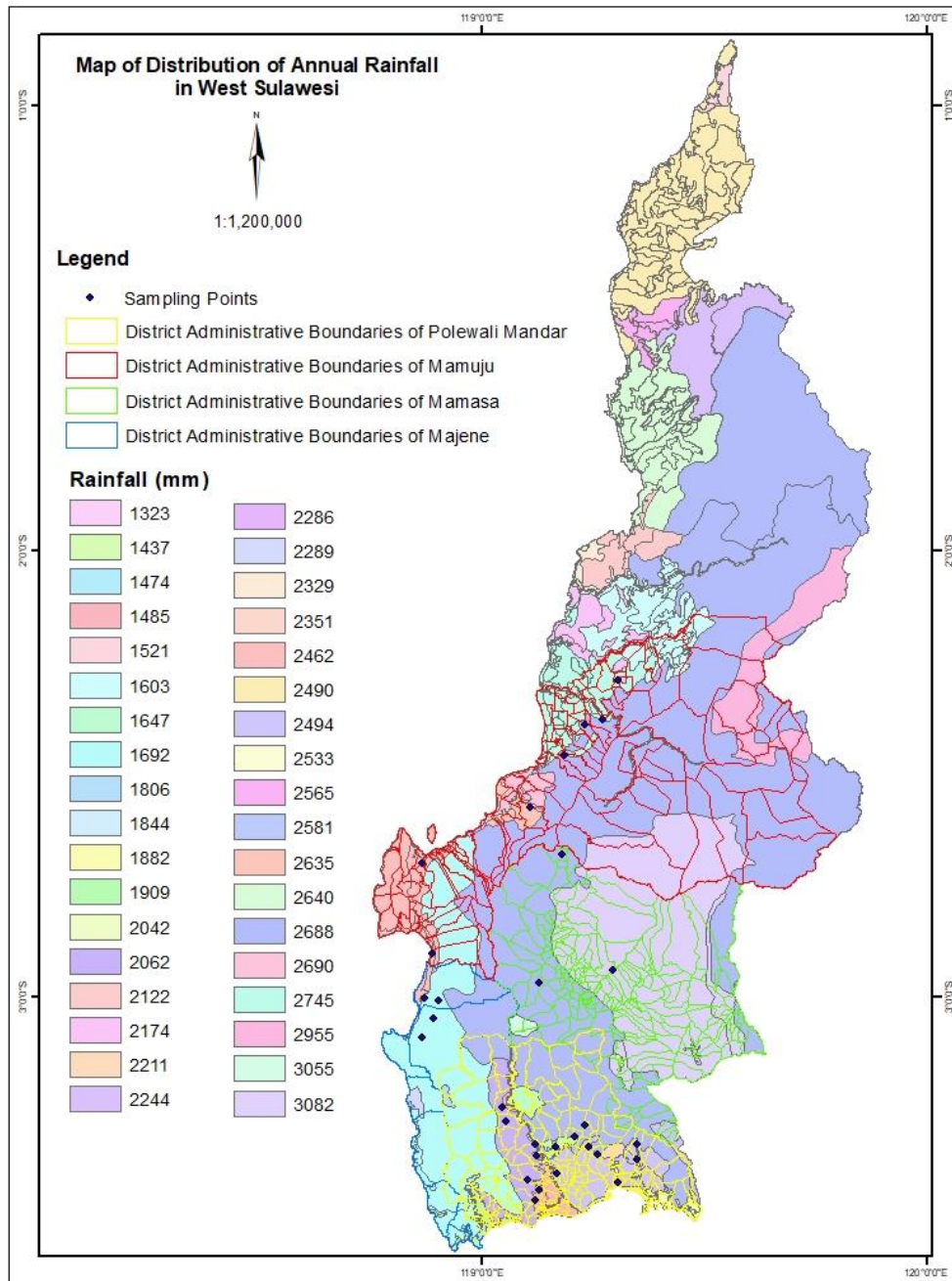


Figure 1. Map of distribution of annual rainfall in West Sulawesi.

The range of soil salinity at all representative points was almost the same, namely 0.20-0.96 dS m⁻¹. The highest salinity was in the research location of Polewali Mandar Regency with high cocoa productivity categories. In contrast, soil salinity with the same range was found in Polewali Mandar Regency with low productivity.

The results of soil analysis showed that the pH H₂O value varied at each representative point. pH H₂O 5.4 - 6.9 are found in Polewali Mandar regency, Majene pH 5.3 - 6.3, Mamasa 6.2 - 6.7 and Mamuju regency pH 6.4 - 6.7. The soil analysis results also showed a pH of 6.7 (near neutral) found at representative points with a high category of cocoa plant productivity (2,000 kg/ha/year) located in Masoso village, Bambang district, Mamasa regency.

3.3. Land suitability index

The characteristics used in determining the land suitability index include Rainfall, annual average temperature, relative humidity (climatic characteristics). Soil characteristics include: slope (%), soil depth (cm), texture, drainage, surface rock (%), pH H₂O, salinity (dS m⁻¹), c-organic (%), number of bases can be exchanged (cmol (+) kg⁻¹), Cation Exchange Capacity (cmol (+) kg⁻¹) and base saturation (%). The cocoa land suitability index at each sampling point is presented in table 1 and figure 2.

Table 1. The cocoa land suitability index at each sampling point.

No.	Sub-District	District	Regency	Land Suitability Index (%)
1	Padang Timur (A1)	Campalagian	Polman	3.89
2	Tammajarra (A2)	Tommo	Mamuju	3.19
3	Kalonding (A3)	Sampaga	Mamuju	25.43
4	Gattungang (A4)	Campalagian	Polman	3.41
5	Sumarrang (A5)	Campalagian	Polman	24.79
6	Taramanu Tua (A6)	Tutar	Polman	1.09
7	Pullewani (A7)	Tutar	Polman	3.63
8	Salukayu (A8)	Tammeroddo Sendana	Majene	13.45
9	Batupanga Daala (A9)	Luyo	Polman	2.54
10	Pappandangan (A10)	Anreapi	Polman	1.92
11	Pappandangan (A11)	Anreapi	Polman	18.68
12	Sambabo (A12)	Ulumanda	Majene	10.26
13	Patampanua (A13)	Matakali	Polman	16.76
14	Induk Makkombong (A14)	Matakali	Polman	12.83
15	Bonra (A15)	Mapilli	Polman	30.95
16	Landi Kanusuang (A16)	Mapilli	Polman	7.22
17	Batu Ampa (A17)	Papalang	Mamuju	19.09
18	Bussu (A18)	Tapango	Polman	24.06
19	Kayuanguin (A19)	Malunda	Majene	12.99
20	Lombang Timur (A20)	Malunda	Majene	3.01
21	Kabiraan (A21)	Ulumanda	Majene	2.62
22	Masoso (A22)	Bambang	Mamasa	54.65
23	Lakahang (A23)	Tabulahan	Mamasa	4.18
24	Sondoang (A24)	Kalukku	Mamuju	4.35
25	Batupanga (A25)	Luyo	Polman	3.07
26	Salupangi (A26)	Simboro	Mamuju	9.89
27	Taan (A27)	Tapalang	Mamuju	3.04
28	Batu (A28)	Tapango	Polman	8.45
29	Pamoseang (A29)	Mambi	Mamasa	4.01
30	Benato Rejo (A30)	Tapango	Polman	8.82

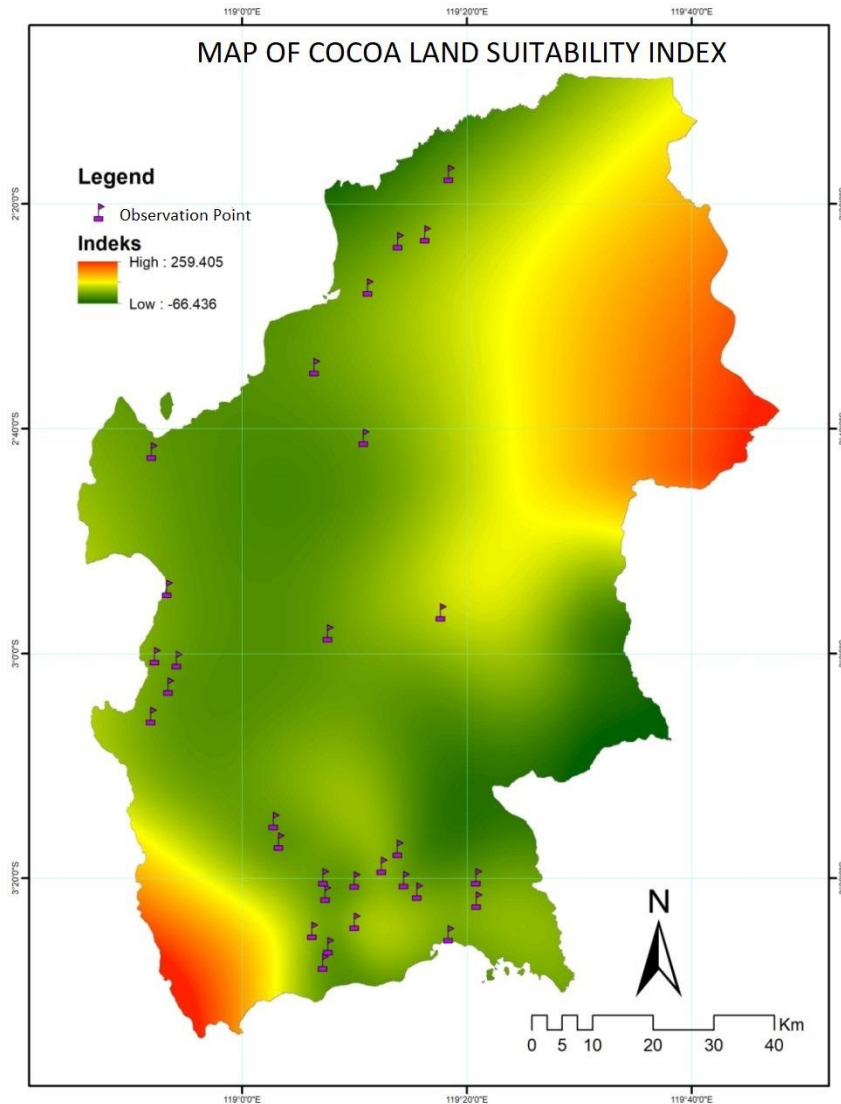


Figure 2. Map of cocoa land suitability index in West Sulawesi.

Based on the land index value obtained, it shows that the index value varies widely. The highest land index value (53.56) was obtained in Masoso village, Bambang district, Mamasa regency (A22), with cocoa productivity reaching 2,000 kg/ha/year. This value is included in the reasonably appropriate category (S2). While the lowest index value was found in Taramanu Tua village, Tutar district, Polewali Mandar regency (A6), with a cocoa plant productivity of only 700 kg /ha/year. The relationship between land index values and cocoa productivity is presented in figure 3.

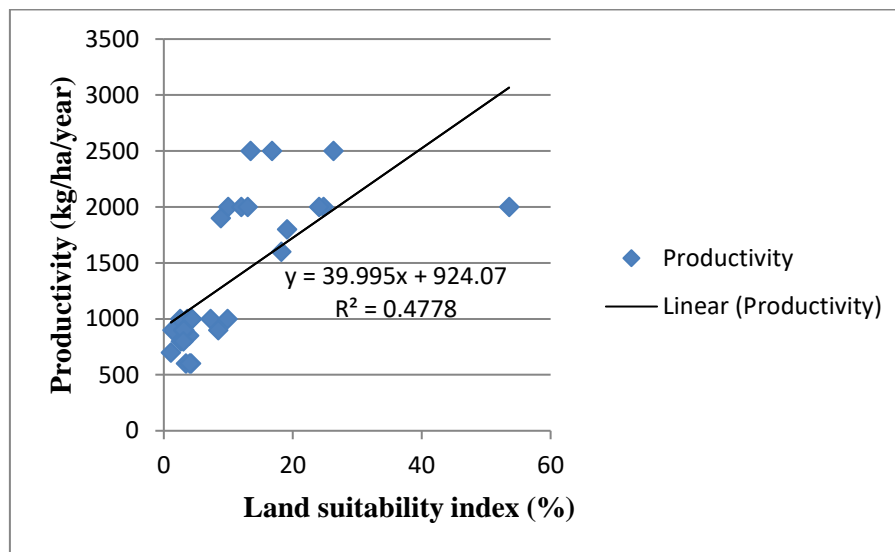


Figure 3. Relationship between land suitability index and cocoa productivity.

The correlation analysis shows that there is a strong relationship (*Multiple R*= 0.69) between the land index and cocoa productivity with the equation $y = 39.99x + 924$ (figure 3) shows that the higher the land index value, the higher the productivity of cocoa. Any increase in land index value will increase cocoa productivity. These results are in agreement the regression equation ($P < 0.001$) indicates that cocoa yield decreases by 16 kg ha^{-1} for every 1% decline in soil quality index di Nigeria [8]. The correlation between LSI and cocoa yield was a strong correlation with a coefficient (r) > 0.9 in Luwu Timur Regency South Sulawesi [5].

4. Conclusions

There is a strong correlation between land index values and cocoa productivity. Each increase in the land index will increase the productivity of specific cocoa plants for the West Sulawesi Region. The highest land index value (53.56) was obtained on land with cocoa productivity of $2,000 \text{ kg /ha/year}$. The lowest Land Suitability Index value is obtained on land with a 700 kg /ha /year productivity.

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