Land suitability evaluation for cocoa (*Theobroma cacao* L.) in Gantarang sub district, Bulukumba, Sulawesi Selatan

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**Abstract.** Gantarang Subdistrict is one of the largest cocoa land areas in Bulukumba Regency, South Sulawesi. However, the production of cocoa plants in Gantarang Subdistrict has not been optimal yet. Therefore, an effort is needed to evaluate cocoa land by establishing land characteristics as a basis for determining the suitability of cocoa plants in Gantarang Subdistrict. This research was conducted using a survey method with the purposive sampling technique through the collection of primary data and secondary data. Data obtained were analyzed using the matching method between land quality and land characteristics as parameters with the criteria of land suitability class. The results showed that the land characteristics in Gantarang Subdistrict varied greatly. The actual land suitability for cocoa plants in Gantarang Subdistrict at the sub-class level based on FAO criteria differs widely. Based on the sub-class level there are 5 actual land suitability classes, which are S3rc, S3nr, S3na, S3eh, and Nrc. Improvements that can be made include adding organic matter, fertilizing, making terracing and conservation. After the improvement, the potential land suitability classes that can be achieved are S2, S3, and N with the biggest limiting factor is by rooting media factor; the rest is by danger of erosion and land preparation factors.

1. **Introduction**

Indonesia is the third largest cacao bean producer in the world with a share of production in 2011 of 16.95% below Ivory Coast and Ghana with a production share of 36.37% and 18.19% respectively. Indonesian cocoa beans production in 2011 was around 712,000 tons, while Ivory Coast and Ghana were 1,276,000 tons and 850,000 tons respectively [1]. From 2013 to 2015, cocoa in Indonesia experienced a decrease in cropping area and production. In 2015, it was noted that cocoa plantations in Indonesia were only 1,724,100 ha with a production of 661,200 tons of dried cocoa beans. The cocoa plantation is mostly managed by the people (97.6%) and the remaining 2.4% is managed by large plantations [2].

Cocoa production centers in Indonesia are located in four provinces, which are South Sulawesi, Central Sulawesi, Southeast Sulawesi, and West Sulawesi. The four provinces contributed cumulative amounts of 65.22%. Central Sulawesi contributed 19.43%, South Sulawesi 17.83%, Southeast Sulawesi 16.28%, and West Sulawesi 11.67% [2].

South Sulawesi province has several cocoa-producing regencies. One of them is Bulukumba Regency which had the lowest contribution compared to the other regencies, which was 3.41% [2]. The average cocoa productivity in Bulukumba in 2014 was only 0.59 tons/ha. This figure is very far compared to productivity in 2011 which reached 0.81 tons/ha. In fact, from 2011 to 2014 there was an increase in the area of cocoa plantations. The low productivity of Bulukumba cocoa is caused by the
existence of a Subdistrict of which the plantation area is relatively broad but with low production, namely Gantarang with the productivity of only 0.48 tons/ha.

One of the main obstacles in cocoa cultivation is the selection of land for cocoa plants that does not consider the soil conditions and climate suitable for the growth of cocoa plants [3] so that the ability of land to support cocoa production optimally is not achieved. Cocoa plants are tropical plants that can grow at 90% of humidity and 18 - 32˚C of temperature. However, at temperatures below 25.5˚C it can inhibit flower formation and decrease plant growth. At high temperatures, however, it will affect the process of protein change and the performance of enzymes causing empty seeds [4, 5]. Because each land use has different characteristics, the development of the cocoa cultivation needs to adjust the growing conditions and the land characteristics in order for the genetic potential of cultivated cacao plants to be expressed well. Therefore, the cultivated land must be suitable [6]. That is why it is necessary to determine land characteristics and evaluate the level of land suitability for cocoa cultivation in Gantarang Subdistrict, Bulukumba, South Sulawesi. Land suitability evaluation is a process of assessing land resources for certain uses. The land suitability evaluation is needed in land use planning so that land can be used optimally, productively and sustainably [7, 8]. The potential and constraints of land use can be identified from the beginning so that land management can be done better and directed in accordance with the commodities to be developed [9, 10].

2. Materials and Methods
This research was conducted from July 2017 to January 2018 in Gantarang Subdistrict, Bulukumba Regency, South Sulawesi using a survey method. Determination of the representative sample was carried out by purposive sampling, based on different altitudes, which were 0 - 600 m.dpl (Figure 1). The collection of secondary data was based on data released by the Central Bureau of Statistics of Bulukumba Regency, including temperature, rainfall, and humidity. Field observations were conducted on parameters of oxygen availability, danger of erosion, danger of flood, and land preparation. Soil samples were collected to a depth of 100 cm, according to the distribution of cocoa roots. Soil samples were analyzed based on criteria of land suitability [10], including availability of oxygen, root media, nutrient retention, and available nutrients. Meanwhile, the method of soil analysis was in accordance with the stages of soil analysis issued by Prasetyo et al. [11].

The data obtained were interpreted based on the concept of land evaluation with a matching process between the land characteristics as a parameter for land use requirements that had been arranged based on land units to determine the classes of land suitability. The process of determining these classes was based on limiting factors that refer to the minimum law that the land suitability class is determined by the smallest value. The assessment of land suitability was carried out at the sub-class level based on the land suitability classification structure [9, 10], which are: S1 (very suitable); S2 (quite suitable); S3 (marginally suitable); and N (not suitable). The criteria of land suitability for cocoa are presented in Table 1.

3. Results and Discussions
Gantarang is one of the Subdistricts in Bulukumba Regency, South Sulawesi. The average temperature was measured at 26.5˚C. The average rainfall was 1,848.03 mm/year for the past ten years. The number of wet months was 8.7 and that of dry months was 2.6 [12]. Based on climate data, Gantarang Subdistrict is suitable for cocoa cultivation, with the criteria of S1 land suitability. Based on the dry month, Gantarang Subdistrict is included in the criteria of S2 land suitability class, which is quite suitable, with the number of dry months between 2-3 months.

The observations in the field showed that the availability of oxygen in Gantarang Subdistrict started from rather inhibited until good. The availability of oxygen was indicated by the ability of soil drainage. In water saturated conditions, the O2 content is small and CO2 increases so that it will inhibit root growth which then affects the process of water and nutrients suctioning. Rough material found was very varied with an effective depth of between 50 ± 100 cm. The effective depth of the soil is the depth of the soil that can still be reached by plant roots. The effective depth of soil affects the
growth of plant roots, water content and nutrients in the soil. Cocoa plants need soil with a depth of more than 100 cm. Based on the observation results, most of Gantarang Subdistrict has an effective depth of 50-75 cm, meaning that it is categorized in the class which is suitable to marginal (S3).

![Figure 1. Soil sample distribution map.](image)

Nutrient retention is a parameter associated with soil productivity on plants. There are several land characteristics to determine nutrient retention of a soil, such as cation-exchange capacity (CEC), base saturation, pH, and C-organic content. Cocoa plants require a CEC value of more than 16 (cmol.kg⁻¹). Based on the results of laboratory analysis it can be seen that most of the observed CECs of soil are more than 16 (cmol.kg⁻¹) which means very suitable (S1) for the growth of cocoa plants. The higher the CEC value of the soil, the easier the soil will be to absorb cations.

Base saturation is an indicator to determine the level of chemical fertility in the soil. Soil is very fertile if the base saturation is more than 80%. Cocoa plants require more than 35% base saturation so that they can grow and produce optimally. The results of the analysis of soil base saturation in Gantarang Subdistrict are above 80% on average, which means it has S1 land suitability class indicating that the base saturation is very suitable for cocoa plantations. The results of the analysis of soil pH show that the average soil in Gantarang Subdistrict is very suitable for cocoa cultivation, with S1 land suitability class, which is in the range of 6.0-7.0.

C-Organic is an organic carbon content derived from organic matter contained in the soil. Laboratory test results showed that the measured C-organic was > 1.2%. That is, based on land suitability for cocoa plants, included in the S1 class (very suitable). The high content of organic matter provides better soil porosity and permeability so that air aeration increases.
Table 1. Criteria of land suitability for cocoa plants [10, 13].

| Use Requirements / Land Characteristics | Classes of Land Suitability | N |
|----------------------------------------|-----------------------------|---|
| **Temperature (tc)**                  |                             |   |
| Average Temperature (°C)              | S1 25 – 28                  | S2 20 - 25 | S3 32 – 35 | < 20 |
|                                        | S1 28 - 32                  | S2 25 – 30 | S3 35 – 38 | > 35 |
| **Water availability (wa)**           |                             |   |
| Rainfall (mm) during the growth period| S1 1.500 - 2.500            | S2 2.500 – 3.000 | S3 3.000 - 4.000 | < 1.250 |
| Duration of dry period (months)       | S1 1-2                      | S2 2 - 3  | S3 3 – 4   | > 4  |
| Humidity (%)                          | S1 40-65                    | S2 65-75 | S3 75-85 | > 85  |
|                                        |                             | S2 35-40 | S3 30-35 | <30  |
| **Oxygen Availability (oa)**          |                             |   |
| Drainage                               | Good, moderate              | Rather inhibited | Inhibited, rather fast | very inhibited, fast |
| Rooting media (rc)                     |                             |   |
| Texture                               | Soft, rather soft           | Moderate | Rather rough, very soft | Rough |
| Rough material (%)                    | S1 < 15                     | S2 15 - 35 | S3 35 – 55 | > 55  |
| Depth of land (cm)                    | S1 >100                     | S2 75 – 100 | S3 50 – 75 | < 50  |
| **Peat moss:**                        |                             |   |
| Thickness (cm)                         | S1 < 100                    | S2 100-200 | S3 200-300 | > 300 |
| Maturity                               | Saprik (ripe)               | Saprik, hemik (ripe, half-ripe) | Hemik (half-ripe) | Fibrik (raw) |
| **Nutrient retention (nr)**           |                             |   |
| Land CEC (cmol)                        | S1 >16                      | S2 5-16 | < 5  |
| Base Saturation (%)                   | S1 >35                      | S2 20-35 | < 20 |
| pH H2O                                | S1 6.0-7.0                  | S2 5.5-6.0 | < 5.5 |
|                                        | S1 >7.0                     | S2 7.0-7.6 | < 7.6 |
| C-Organic (%)                         | S1 >1.2                     | S2 0.8-1.2 | <0.8 |
| **Available Nutrients (na)**          |                             |   |
| N total (%)                            | Moderate                    | Low | Very Low |
| P2O5 (mg.kg⁻¹)                         | Moderate                    | Low | Very Low |
| K2O (cmol (+).kg⁻¹)                    | High                       | Moderate | Low-Very low |
| **Danger of Erosion (eh)**            |                             |   |
| Slope (%)                              | < 8                         | S2 8 - 15 | S3 15 – 30 | > 30  |
| Danger of Erosion                      | sangat rendah               | rendah - sedang | Berat | sangat berat |
| **Danger of flooding / inundation during the planting period (fh)** |                 |   |
| Height (cm)                            | -                           | - | 25 | > 25 |
| Duration (days)                        | -                           | - | <7 | ≥ 7 |
| **Land preparation (lp)**              |                             |   |
| Rocks on the surface (%)              | S1 < 5                      | S2 5 – 15 | S3 15 – 40 | > 40  |
| Rock outcrop (%)                       | S1 < 5                      | S2 5 – 15 | S3 15 – 25 | > 25  |

Another factor that affects plant growth is nutrient availability. The test results of available nutrients include total N, P₂O₅ and K₂O levels. The N content had a very high total average, which was > 1%. The average P₂O₅ content was very low to very high. This difference was limited by the presence of the Bialo River, where the area to the east of the river had very low P₂O₅ content, i.e. < 4 cmol⁺⁺.kg⁻¹ and was included in the S3 land suitability class (suitable to marginal), while the one in the west of the river had moderate to very high P₂O₅ content (17.39-76.77 cmol⁺⁺.kg⁻¹) and was included in the land
suitability class which was very suitable (S1). Test results on K₂O content showed initial results from very low to low. Average K₂O content was low (0.11-0.35 cmol(+)/kg⁻¹) making the majority of the Gantarang Subdistrict area into the land suitability class which was according to marginal (S3).

Table 2. Land suitability class for cocoa plants in Gantarang Subdistrict, Bulukumba Regency.

| Zones | Actual land suitability class | Improvement Efforts | Assumption of Improvement Level | Potential land suitability class |
|-------|------------------------------|---------------------|---------------------------------|---------------------------------|
| Zone 1 | S3rc                         | Unable to be done    | -                               | S3rc                            |
|        | S3nr                         | Addition of organic matter | Moderate                   |                                  |
|        | S3na                         | Fertilization        | Moderate                       |                                  |
| Zone 2 | S3rc                         | Unable to be done    | -                               | S3rc                            |
|        | S3na                         | Fertilization        | Moderate                       |                                  |
| Zone 3 | S3na                         | Fertilization        | Moderate                       | S2rc-1p                        |
| Zone 4 | S3rc                         | Unable to be done    | -                               | S3rc                            |
|        | S3na                         | Fertilization        | Moderate                       |                                  |
| Zone 5 | S3na                         | Fertilization        | Moderate                       | S3rc                            |
|        | S3eh                         | Making terraces and conservation | Moderate              | S3rc                            |
| Zone 6 | S3eh                         | Making terraces and conservation | Moderate | S2eh                            |
| Zone 7 | Nrc                          | Unable to be done    | -                               | Nrc                             |
|        | S3rc                         | Unable to be done    | -                               |                                  |
| Zone 8 | S3nr                         | Addition of organic matter | Moderate                   | S3rc                            |
|        | S3na                         | Fertilization        | Moderate                       |                                  |
| Zone 9 | S3rc                         | Unable to be done    | -                               | S3rc                            |
|        | S3na                         | Fertilization        | Moderate                       |                                  |
| Zone 10| S3na                         | Fertilization        | High                           | S2rc                            |
| Zone 11| Nrc                          | Unable to be done    | -                               | Nrc                             |
|        | S3rc                         | Unable to be done    | -                               |                                  |
| Zone 12| S3na                         | Fertilization        | Moderate                       |                                  |
|        | S3eh                         | Making terraces and conservation | Moderate              | S3rc                            |

In addition to the above factors, the danger of erosion, danger of flood, and land preparation are also determining factors in land suitability. The danger of erosion is strongly affected by the slope of the land. Based on the survey results, Gantarang Subdistrict had a slope of 0-12% with a flat to hilly area. In such conditions, the danger of erosion identified was very low to moderate. Based on criteria of land suitability, the area with an altitude of 500-600 meters above of the sea level land slope measured at 16-23% should be included in the class which was suitable to marginal (S3), whereas for the height of 0-300 meters above of the sea level, it was included in the S1 land suitability class (very suitable). Measured danger of erosion ranged from very low to moderate, according to the slope of existing land.

Gantarang Subdistrict is an area that has never been flooded. This condition makes the class of land suitability to the danger of flood is S1 (very suitable). Given the number of rocks on the surface, based on the survey results, it can be known that the number of rocks on the surface is included in the S2
class (suitable) to S1 (very suitable). The rock on the surface is the volume of rock that is on the surface of the soil or an overlay that has a diameter of more than 25 cm. The abundant number of rocks on the surface of the soil causes roots difficult to find nutrients. Rocks on the surface rock make it difficult to process the soil because it has a large volume and is hard textured.

Based on the description above, the results of land suitability evaluation in Gantarang Subdistrict are presented in Table 2. The actual and potential land suitability maps of cocoa cultivation in Gantarang Subdistrict are presented in Figure 2 and 3.

![Figure 2. Map of actual land suitability for cacao plants in Gantarang Subdistrict, Bulukumba, South Sulawesi.](image-url)
4. Conclusion
Gantarang Subdistrict is a region with very varied characteristics. The measured temperature was 26.5°C, the rainfall was 1848.30 mm/year, the dry month was 2.6 months/year, and the soil drainage was from rather inhibited to good. The effective depth was measured moderate to deep, the CEC was moderate to high with high base saturation. The pH of the soil was measured neutral, high C-organic, high total N, P₂O₅ was very low to high and K₂O was relatively low. The danger of erosion was measured very low to moderate, the danger of flood was very low, the slope was flat to rather steep, and the number of rocks on the surface and rock outcrops was moderate.

The actual land suitability for cocoa plants in Gantarang Subdistrict at the sub-class level based on FAO criteria varied greatly. Based on the sub-class level there were 5 actual land suitability classes, which were S3rc, S3nr, S3na, S3eh, and Nrc.

Potential land suitability classes for cocoa plants in Gantarang Subdistrict based on FAO standards were S2, S3, and N, which means they were quite suitable, marginally suitable, and not suitable to with some limiting factors. The majority of land was limited by rooting media factors; the rest was by the danger of erosion and land preparation factors.

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