International Journal on Advanced Science Engineering Information Technology

Vol.13 (2023) No. 1
ISSN: 2088-5334

Evaluation of Land Suitability for Cacao in Takapala Watershed Using Geographic Information System

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***Abstract*— Due to the great variety of land resources in Indonesia, there is a wide range of levels of land appropriateness for various commodities. In order to provide the most physically feasible cultivation pattern and the greatest possible economic results, a land plan is required. This study aims to determine the suitability level of cocoa plantations in the Takapala Watershed (Jeneberang Sub-watershed) using a geographic information system (GIS) method with overlays of slope maps, geomorphological maps, soil type maps, and land use maps. According to the analysis's findings, the Takapala watershed's area is suitable for growing cocoa (Jeneberang Sub-watershed). Obtaining five land suitability sub-classes, including S2 extremely appropriate (with a 93.94 ha area), S3-W1 (marginally suitable class with a factor of 0.8), and S4-W1 (not at all suitable class) as a limiting factor for rainfall 1022.33 Ha with marginally suitable class. There is very good potential for cocoa plant growth in the Takapala Watershed, where the land adaptability level can reach 69.6%. This demonstrates that cocoa trees can develop into crops that can be grown in the Takapala watershed. On the one hand, the Takapala Watershed's topography will present a barrier to cacao development, needing specific approaches to cacao production. Future research should, it is anticipated, look into how cocoa plants should be managed in environments with steep-to-steep slopes.**

***Keywords*— Land suitability; cacao; Geographic Information System; GIS.**

Manuscript received 17 Jan. 2022; revised 18 Dec. 2022; accepted 30 Jan. 2023. Date of publication 28 Feb. 2023.

I. INTRODUCTION

The level of land suitability for commodities varies widely because land resources in Indonesia are very diverse. Therefore, a land plan is needed to guarantee the most physically suitable cultivation pattern [1]–[4] so that it can provide the best results economically [5]. Good land use planning must focus on the availability and suitability of land resources [6]. Land use planning aims to obtain alternative land uses and the best land use to meet human needs while maintaining the availability of land for future use [7]. Current technological developments make it easier to analyze land suitability; one of them is information based on geographic information systems (GIS) [8].

Due to Indonesia's broad variety of land resources, there is a wide range of land uses for commodities. A land plan is therefore required to provide the most physically appropriate farming pattern to achieve the greatest economic outcomes. The accessibility and suitability of land resources must be a priority in sound land use planning. Land use planning aims to find other uses for the land and choose the best one to suit human requirements while preserving the land's availability for other uses in the future. Technical advancements have made analyzing land suitability simpler, one of which is data from GIS.

Mapping with a geographic information system (GIS) is an effective way to understand land characteristics and their potential for development in predicting land suitability evaluations [9], [10]. Land capability classification is a systematic land assessment that classifies it into several categories based on the available potential properties [11]. Determination of land suitability classes is carried out so that natural resource management is under its function [12]. The suitability between the physical environmental characteristics of an area and the requirements for the use or the commodity under consideration offers an overview or information suggesting that the land has the possibility exists to use the land for producing a specific commodity [13].

Theobroma cacao L., a tree that is grown on plantations and has its origins in South America, is typically grown in diverse tropical climates. This plant's seeds are used to make processed food known as chocolate [14]. The natural habitat of the cocoa plant is in tropical forests. Cocoa or cocoa is a shade-loving tropical plant with a yield potential of 50-120

fruits per year [14]. Cocoa frequently grows in clumps along riverbanks, where the roots may be submerged for significant stretches of the year. Cocoa thrives at low elevations, typically below 300 meters above sea level, in regions with annual rainfall ranging from 1,000 to 3,000 mm [15]. Cocoa is a native plant of Mexico, Central America, and northern Brazil [16].

Cacao varieties, including *Criollo* (fine cocoa or noble cocoa), dominated the cocoa market until the mid-18th century [17]. However, today only a few *criollo* trees remain. Next is the *Forastero,* the largest group of varieties that are processed and planted, then there is the *Trinitario* which is the result of a cross between the *Forastero* and *Criollo* types [18]. *Forastero* is more suitable in the lowlands, while *Criollo* can be planted up to a fairly high altitude. *Criollo* linked to the earliest *Criollos* of Central America, Mexico, and the Andes (Peru, Chile, Argentina, Ecuador, Colombia, Bolivia, and Venezuela) [19]. Upper Amazon, Lower Amazon, Orinoco, and the Guianas are just a few of the many populations that make up the Forastero group, all of which have various geographic origins [20]. It can be argued that cocoa is one of the top plantation products with a significant impact on the Indonesian economy [21]–[24]. With the increasing world population, the demand for cocoa commodities will also increase. Besides that, cocoa production is not always stable, and the increase is not always significant from year to year [25]. However, avoiding the obstacle in developing cocoa requires the selection of land for cocoa plantations that consider the soil and climate conditions suitable for cocoa plantations [26].

The acreage and production of cocoa in Indonesia have also risen significantly over the past ten years, at a rate of 5.99% annually [27]. The area of cocoa plantations in Indonesia in 2017 was 1,653.1 thousand hectares, with a production of 593.8 thousand tons of cocoa beans with a productivity of 0.353 tons/ha [28]. In 2016, it was recorded that the area of cocoa plantations in Sulawesi was 240,073.00 hectares, with a production of 151,392.00 tons of cocoa beans and a productivity of 0.63 tons/ha. One of the areas that have the potential to grow cocoa or cocoa is the Indonesian region, to be precise, in the eastern part of South Sulawesi province, which has a climate and topography suitable for cocoa or cocoa plantations. Takapala watershed is a watershed located in the upstream Jeneberang Sub-watershed, Gowa Regency, and is a watershed that receives rainwater and drains it into tributaries towards the main river, the Jeneberang River. Geographically, the Jeneberang Watershed is located at 19 0 23' 50" E-119 056'10" E and 05 0 10" South Latitude- 05 0 26' 00" South Latitude, with the length of the main river being 78.75 km. The area of the Jeneberang watershed is 860 km2, while the river area is 9,331 km2. The topography of the Takapala watershed has a variety of evaluations, this can be seen at the highest elevation point, which is approximately 2024 masl, and the lowest elevation point is approximately 900 masl with the land cover of the Takapala watershed, namely forests, rice fields, settlements and fields and shrubs that appear on the map, and Indonesian landscape [29].

The cultivation of cocoa plants in a field must go through several systematic technical steps. One of which is by using the necessary mapping resources, so by looking at this, efforts are needed to assess or see how the land suitability of the plantations in the Takapala Jeneberang watershed is, whether it is suitable for the land used. For the cultivation of cacao plants in the Jeneberang Takapala Watershed, a title that represents this was proclaimed, namely "Land Suitability for Cacao Planting in the Takapala Jeneberang Watershed."

II. Materials and Method

A. Materials

The parameters used in this study consisted of a slope, land use, landform, and soil type. All parameters will be given a scoring value for each indicator which is then subjected to overlay analysis. The overlay is an essential spatial analysis that combines two or more data and their attributes as input and produces a new map from the combination [30]. The results of this analysis were then used as assumptions in making a cocoa plantation land suitability map for the Takapala Jeneberang Sub-watershed, Gowa Regency.

B. Research Setting and Method

The research location is located in the Takapala Watershed, Gowa Regency, Indonesia. Based on the astronomical location, the research location is at 5º 15'0" - 5º 17'0" South Latitude (South Latitude) and 119º 52'30" - 119º 55'0" East Longitude (East Longitude) with an area of around 2.129 hectares or 21. 29 km2 with the highest elevation point of 2,024 meters, while the lowest elevation is 995 meters. The accompanying Figure 1 displays a map of the study site.

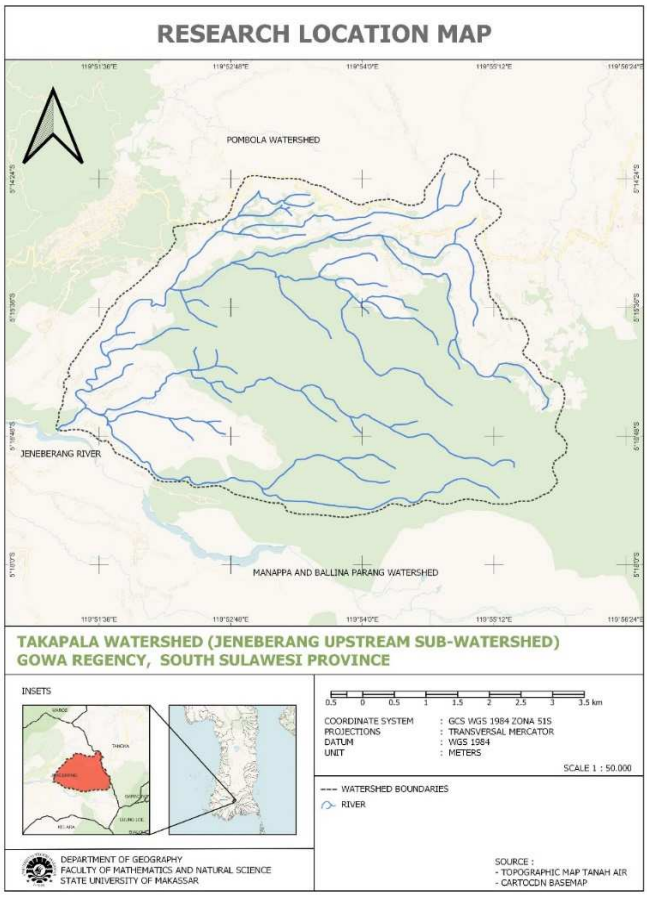

Fig. 1 Study area: Takapala watershed, Gowa Regency, Indonesia

III. Results and Discussion

A. Land Use

Land use in the Takapala Watershed is divided into 6 (six) categories of land use: shrubs, forest, residential paddy fields, rain-fed paddy fields, and dry fields/fields. Based on the conditions of land use, it can be seen that the forest area has the most dominant area, with an area of 1,837.4 hectares, while the narrowest area is a residential area, with an area of only 16.11 hectares. The visualization of land use in the Takapala watershed can be seen in the following Figure 2.

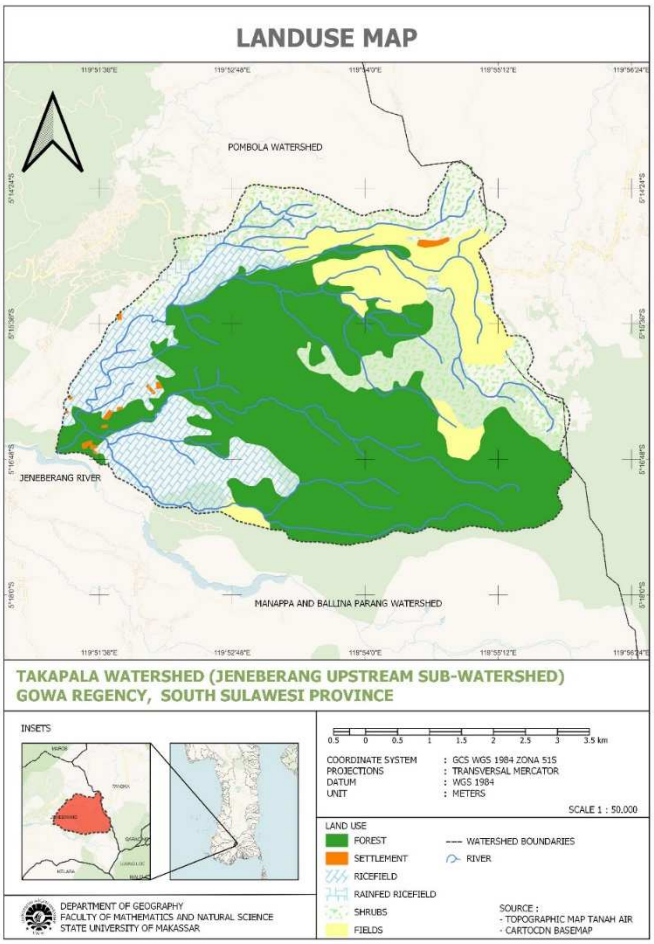

Fig. 2 Land use Map of Takapala Watershed

B. Slope

In general, the slope conditions in the Takalapa Watershed are dominated by areas with sloping to slightly steep topography with a slope class of 8-25%. The topographical conditions are rather steep to steep, which can potentially experience erosion that affects cacao plants, while flat to sloping topographic conditions have a more positive effect on cacao plants. The visualization of topographical conditions in the Takapala watershed can be seen in Figure 3.

C. Soil

The Takapala Watershed has 2 (two) soil types, namely Brown Andosol and Yellowish-Brown Latosol. The clay class generally dominates the soil texture in the study area. The visualization of soil-type conditions in the Takapala watershed can be seen in Figure 4.

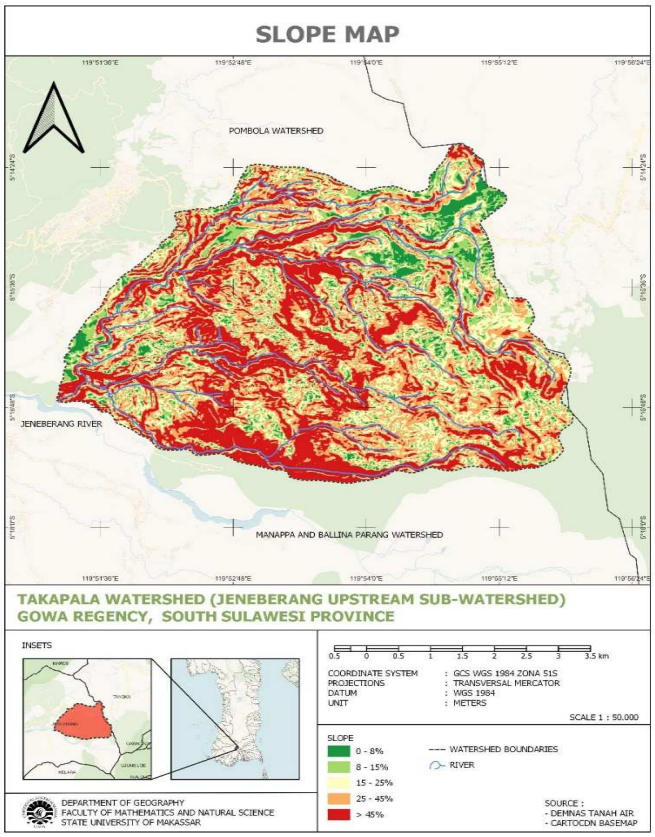

Fig. 3 Slope map of Takapala Watershed

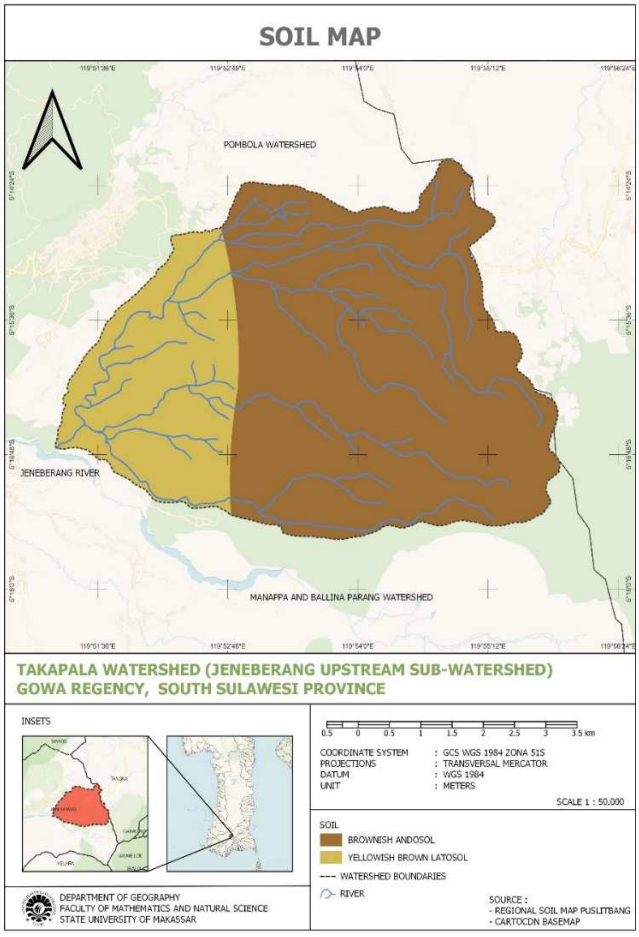

Fig. 4 Soil Map of Takapala Watershed

D. *Landform*

Denudational hills and denudational mountains are landforms in the Takapala Watershed. The landform is one of the important parameters in determining land suitability for cacao plants because this will affect soil conditions including soil fertility. The visualization of landform conditions in the Takapala watershed can be seen in the following Figure 5.

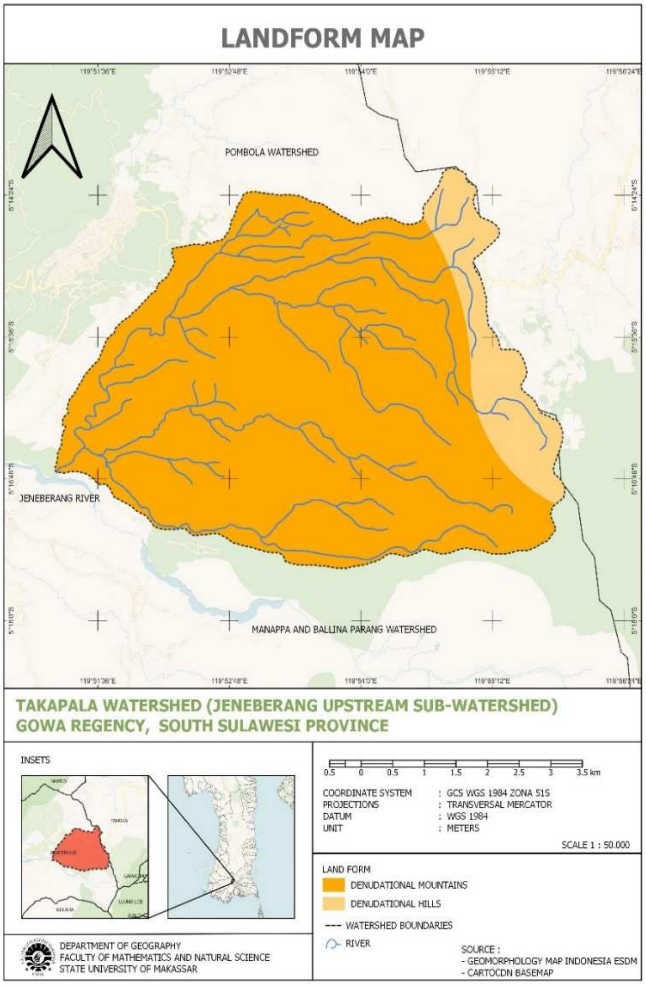

Fig. 5 Landform map of Takalapa Watershed

E. *Land Suitability for Cacao Plants*

Land suitability analysis was carried out using the overlay method, which overlays each parameter that has been given a score and weight. From the analysis results, the number of categorizations of land suitability values is obtained in Table 1.

TABLE I
LAND SUITABILITY CATEGORIES

Land Suitability	Categories	Area (hectare)	Percentage (%)
N	Unsuitable	332.72	9.16
S1	Suitable	1195.13	32.91
S2	Moderately Suitable	1333.48	36.72
S3	Marginally Suitable	754.32	20.77
Residence	Built-up area	16.11	0.44
Total		3631.76	

Based on the results of the land suitability analysis for cacao plants, it was found that the Takapala Watershed had a suitable and quite suitable land suitability level of 69.6%, while only 9.1% were not suitable. This shows that the Takapala watershed has the potential to develop cacao plantations. The visualization of land suitability data for the Takapala watershed can be seen in the following Figure 6.

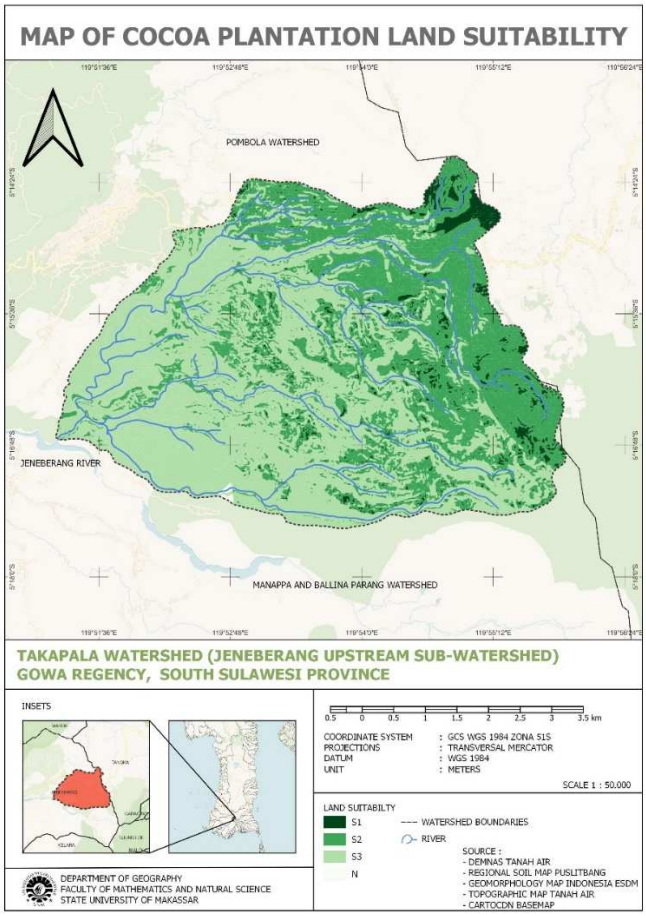

Fig. 6 Map of Land Suitability for Cacao Plants

The Takapala Watershed has quite a good potential for developing cacao plantations. It is shown from the results of the analysis that the potential for land suitability is at 69.6%. Seeing the good potential for cacao development, this can be a reference for the community and local government in developing cacao plants so that cacao production in Gowa Regency can increase. Another factor that can be an obstacle to the development of cacao in the Takalapa watershed area is the topographical condition which is dominated by steep to steep slopes. This topographical condition can affect soil erosion which can cause cacao productivity. In addition, steep topographical conditions can also be an obstacle in transporting cacao production.

IV. CONCLUSION

Land suitability for cacao plants in the Takapala Watershed has very good potential, with a land suitability level of up to 69.6%. This proves that cacao plants can become plants that can be cultivated in the Takapala watershed area. On the one hand, the condition of the Takapala Watershed, which has a rather steep topography, will be a challenge in cacao development, so special approaches are needed in cacao

cultivation. Therefore, it is hoped that future studies to examine the management of cacao plants in areas with steep-to-steep slopes.

The level of land adaptability of the Takapala Watershed has very strong potential for cocoa plantations, demonstrating that cocoa plants can develop into cultivable plants in the Takapala watershed region. The Takapala Watershed's state has a rather steep topography, which would present a barrier to cacao development, necessitating particular approaches to cacao production. Therefore, future research is planned to look at how cocoa trees are managed in locations with steep slopes.

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