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Land Suitability for Cocoa Development in South Sulawesi: An Analysis using GIS and Parametric Approach

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Abstract. In South Sulawesi, the regional program for prime commodity development has been implemented by the provincial government, as part of promoting regional spatial planning program. In some parts of the region, cultivation of cocoa (*Theobroma cacao* L.) as prime commodity has long been practiced in different soil environment. Therefore, there is a need for information that will allow land managers to identify both the inherent land suitability, and the spatial distribution of land areas where possible development can be implemented taking into account present land use types. This paper describes a spatial based quantitative suitability evaluation of land for cocoa production. This research was carried out in the one of the cocoa-producing districts in South Sulawesi, District of Luwu Timur. The research project implements land suitability evaluation method based on the spatial-quantitative approaches in Geographical Information Systems (GIS). The main sources of data bases used include digital topographic map, land use map, soil map and soil characteristics derived from available data at reconnaissance level and semi detailed survey, climate data, and satellite imagery. The results of analysis of potential development area for cocoa cultivation show that more than 90 percent of study region are suitable (at S2 and S3 classes) for cocoa cultivation. This study reveals that there are some limiting factors in term of chemical and physical soil characteristics that can still be improved, but there will be almost no limitation in terms of land cover type for cocoa development.

1. Introduction

Cocoa is one of the main plantation crops in South Sulawesi Province, Indonesia. It grows along the tropical zones of Sulawesi Regions. Recently, its productivity become decrease and limited by a rapid growth of other land use types, suppressing land for cocoa cultivation. In this paper, we focused our analysis on one main district which produced cocoa in South Sulawesi, District of Luwu Timur. Evaluation of agroecological suitability (land suitability) will emphasize the analysis of the diversity of land characteristics, because it will determine the type of commodity that can be cultivated, which in its sequence determines the level of land productivity. The development of agricultural commodities in areas that are in accordance with the requirements of the plant climatic climates (climate, soil, and topography) [1] and socio-economic conditions, coupled with management based on land characteristics, will provide optimal and sustainable results. This study examines land suitability for cocoa in South Sulawesi using quantitative approach based on GIS.

2 Methodology

The study employed integrated techniques of ground surveys and geographic information systems (GIS) technology. Land suitability evaluation for cocoa was performed using the parametric approach then the land suitability index (LSI) analyzed with Storrie method [2]. This study covers survey



activities and laboratory analysis, guided by Landon [3]. Classification of land suitability was made at subclass level [4]. Land suitability classification is undertaken based on the level of detail of the data available. For example, in this study S order is divided into Highly Suitable (S1), Moderately Suitable (S2), and Marginally Suitable (S3). In the “Not Suitable” order no further division is made. Field surveys were conducted to find out actual condition on the ground of cocoa plants that represents a wide range of physical environments within the study area [5]. A spatial based procedure was developed to integrate the information obtained from field surveys and spatial data bases from map [6]. Furthermore, a correlation analysis between the land suitability index and the actual cocoa yield obtained in the field was carried out using Pearson’s correlation analysis. This research was carried out on 21 land systems found in District Luwu Timur, South Sulawesi Province based on land system map [7] (Figure 1 and 2).

3. Result and Discussion

The research area is classified as climate type A [8], which means the distribution of precipitation is evenly distributed throughout the year with annual average rainfall > 3,000 mm. Based on the map of the land system sheet number 2113 (Palopo) [7] with map scale 1:250.000, the main land system in East Luwu Regency consists of 8 types namely: coastal, alluvial plain, swamp, fan and lahar, terrace, plains, hills, and mountains. The East Luwu land system is dominated by mountainous land systems with parent material or ultramafic dominant minerals. The LNG, OKI and BPD land systems are very widest in East Luwu. In addition to the mountainous land system, the alluvial plain land system, namely KHY, is dominant in the area close to the Bone Bay in addition to the coastal land system (PTG). Based on the soil taxonomy system [9], soils in East Luwu district is divided into six orders, namely Histosols, Entisols, Inceptisols, Alfisols, Ultisols and Oxisols.

A preliminary stage of the study has been undertaken to produce land suitability map for cocoa (in the 2017). The former uses FAO method [10], and the later utilizing the parametric combining with image analysis. Land suitability class can be seen in Table 1. As the table and figure shows, no land suitability class S1 exists in the study area, but class S2 (moderately suitable), S3 (marginally suitable) and unsuitable (N).

Table 1. Land suitability area for cocoa at different class

| Category | Description | Limiting factors | LSI | Area (ha) | % |
|----------|---------------------|---|-------|-----------|------|
| S2 | Moderately Suitable | Nutrient availability (pH slightly acid, moderate CEC, moderate C-organic) | 50-75 | 86.315 | 33,3 |
| S3 | Marginally Suitable | Nutrient availability (pH acid, low CEC, low C-organic); hilly slope; erosion hazard, poor drainage | 25-50 | 150.392 | 58,0 |
| N | Unsuitable | Poor drainage, flooding | <25 | 22.619 | 8,7 |
| | | | Total | 259.326 | 100 |

Note: LSI=land suitability index

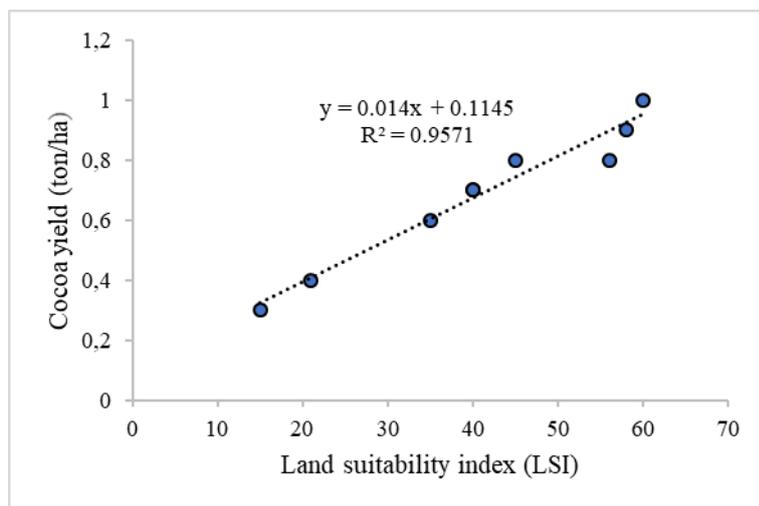
The evaluation results indicate that the main limiting factor for the development of cocoa in this region were the problems of soil fertility, mainly acidic pH, low organic C, low CEC. In addition, the problems of poor surface drainage and flooding were limiting to optimal cocoa growth and production. This can be found in several sub-districts in East Luwu District, among others in Malili, Towuti, Burau, Mangkutana and Wasuponda.

Table 2. The correlation between land suitability index with cocoa yield

| Subclass | Mean LSI | Cocoa yields (ton/ha) |
|----------|----------|-----------------------|
| S2c,f | 60 | 1.0 |
| S2c,t | 58 | 0.9 |
| S2c,f,t | 56 | 0.8 |
| S3f,w | 45 | 0.8 |
| S3f,s,w | 40 | 0.7 |
| S3f,t | 40 | 0.7 |
| S3f,s,t | 35 | 0.6 |
| Nw | 21 | 0.4 |
| Nw, f | 15 | 0.3 |

Note: c: climate; f: fertility; t: topography; s: soil physics; w: wetness

The results of the correlation analysis between LSI and cocoa yields showed a very strong relationship as indicated by the Pearson's correlation coefficient $r = 0.978$; $p < 0.05$ or determination coefficient $R^2 = 0.9571$ with equation $y = 0.014x + 0.1145$. The results of this analysis indicate that along with the increase in LSI values, it was accompanied by an increase in cocoa yields at the study sites. This is shown in Fig.3.

**Figure 3.** The correlation between LSI with cocoa yield

4. Conclusion

The results of this study were in form of a series of land use information (geographic and descriptive), and land suitability for cocoa. The results of analysis of potential development area for cocoa cultivation show that more than 90 percent of study region are suitable (at S2 and S3 classes) with land suitability index ranged from 35 to 60, then 10 % are unsuitable (N) for cocoa cultivation with LSI < 25. The correlation between LSI and cocoa yield were strong correlation with coefficient (r) > 0.9. Cocoa yield from the research site ranged from 0.3 to 1.0 ton/ha and classified as low to medium productivity.

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