Land Suitability of Sebatik Island for Cocoa
(Theobroma cacao L.)

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Abstract. The purpose of this research is to find out the land suitability class on Sebatik Island, Nunukan Regency, North Kalimantan Province for cocoa (Theobroma cacao L.) in accordance with the agroecosystem of the area. The method of this research is a literature study and field survey, sampling and soil analysis in the laboratory, and interviews to determine the land condition and potential of the land for cocoa. The results of the study show that land suitability class on Sebatik Island for cocoa, which is quite suitable (S2) 1.94% of the total area (473,36 ha), land class according to marginal (S3) 88.36% of the total area (21,056 ha), and inappropriate class land (N) 8.52% (2,089 ha). In each land suitability class (S2, S3, N) has a limiting factor for cocoa. The suitability class of S2, the limiting factors are the availability of water (wa), erosion hazards (eh) and nutrient availability (nr). Class S3 the limiting factors are water availability (wa), oxygen availability (oa), erosion hazard (eh), nutrient availability (nr) and rooting condition (rc). In the not suitability class (N), the limiting factor is sulfidic hazards and limited rooting conditions (rc).

Keywords: cocoa, land suitability, Sebatik Island

1. Introduction

Areas in North Kalimantan that border directly with neighboring countries (Malaysia) include the Sebatik Island, Nunukan Regency. This island has an area of 24.4 thousand ha and is located at an altitude of fewer than 400 m above sea level (asl). In the north of this area is a steep rugged elongated, while the more gentle sloping area (plains with corrugated to choppy relief) leads to the border area with the sea. The topography of this area is mostly hilly to mountainous, with slopes of 15 to > 40%

Sebatik Island is in the northern part of Nunukan Regency, and this area in the north is directly bordered by the State of East Malaysia (Sabah), in the west it is bordered by the Nunukan Strait, in the east and south, it is bordered by the Makassar Strait (Sulawesi Sea). The biophysical condition of land for agricultural development on Sebatik Island is associated as critical lands that are vulnerable to the phenomenon of land damage due to erosion, and soil productivity is relatively low. Various problems for development of leading agricultural commodities on Sebatik Island: (a) annual water shortages; (b) land degradation due to erosion on hilly and sloping land, which results in a decline in the quality of soil fertility (depleted soil layers, unstable soil aggregates); (c) the management of the cropping system, the management of land and water in a broad sense at the farm level is inadequate, both from the aspect of natural resource conservation (environmentally friendly) and from the aspect of income sustainability (agribusiness vision). These problems are related to farmer’s mastery of superior commodity cultivation technology (especially cocoa) and relatively inadequate soil and water conservation technology.
Agricultural land for smallholder’s cocoa plantations in the region is generally not well managed so that land productivity and the quality of commodity yields are relatively low [4,5]. The land productivity will affect the yield productivity of the commodity being cultivated [6]. Furthermore, the evaluation of land productivity improvement systems can provide detailed information that will help decision-makers and farmers to identify optimal agricultural management [7].

Declining land productivity is an important issue, especially on sloping agricultural land. Decreased productivity will cause lower soil fertility. One reason is erosion, as a result of inappropriate land management and high rainfall, so that the land becomes damaged, both physical, chemical and biological. Nutrients carried by surface runoff or erosion from a large agricultural land. Nitrogen, phosphorus, and potassium loss from agricultural land is a loss for farmers because these nutrients are necessary if the plants [8]. Therefore, in order to develop cocoa on Sebaik Island, land suitability classes need to be known, to maintain land productivity. The purpose of this study was to determine land suitability classes in Sebatik Island, Nunukan Regency, North Kalimantan Province for the development of cocoa (*Theobroma cacao* L.) in accordance with the agroecosystem.

2. Methodology

The study was conducted on Sebatik Island, Nunukan Regency, North Kalimantan Province. This region is located in the northern part of Nunukan Regency, which is located at coordinates between 117 ° 35’20”- 117 ° 55’31” East Longitude, and 3 ° 57’58”- 4 ° 10’00” North Latitude. The area in the north is directly bordered by State of East Malaysia (Sabah), in the west it is bordered by the Nunukan Strait, in the east and south, it is bordered by the Makassar Strait (Sulawesi Sea). The study was conducted from March to November 2017.

The method used in this research is the study of literature, field surveys, sampling of soil and soil analysis in the laboratory, and interviews. Field surveys were conducted to collect land biophysical and socio-economic data. Soil sampling in the field was chosen purposively based on the site. Each soil observation unit is sampled for analysis of soil physical and chemical properties. Interviews were conducted to: (a) find out the problems, opportunities, hopes and opinions of stakeholders related to the development of leading agricultural commodities, and farming patterns applied; and (b) know the opinion of experts about the increasing sustainable land productivity, especially for smallholder cocoa plantations in the border area of Sebatik Island.

Materials and equipment used are field surveys (biophysical and socio-economic) and support tools (soil drill, pH meter, GPS, compass, chemicals, and questionnaires for interviews). Secondary data needed are climate data, maps (topography, land, land use, administration, agroecological zones of 1:50,000 scale, land use, and other supporting maps). Land suitability analysis is carried out to get suitability of land use on Sebatik Island for cocoa that is in accordance with the suitability class (Table 1) [9].
| Land Use / Characteristics | Land Suitability Class |
|----------------------------|-------------------------|
|                            | S1  | S2  | S3  | N            |
| Temperature (tc)           |     |     |     |              |
| Average temperature (°C)   | 25-28 | 20-25 | 32-35 | <20 and >35 |
| Water availability (wa)    |     |     |     |              |
| Rainfall (mm)              | 1.500-2.500 | -   | 1.250-1.500 | < 1.250 |
|                           | 2.500-3.000 | 3.000-4.400 | > 4.400 |
| Duration of dry period     | 1-2 | 2-3 | 3-4 | > 4          |
| (months)                   |     |     |     |              |
| Humidity (%)               | 40-65 | 65-75 | 75-85 | > 85         |
|                           | 30-40 | 30-35 | < 30  |              |
| Oxygen availability (oa)   |     |     |     |              |
| Drainage                   | good, moderate | rather inhibited drainage | inhibited, rather fast | very inhibited, very fast |
| Rooting media (rc)         |     |     |     |              |
| Texture                    | smooth, rather smooth, medium | - | rather rough, very smooth | rough |
|                           |     |     |     |              |
| Rough material             | < 15 | 15-35 | 35-55 | > 55         |
| Depth of land (cm)         | > 100 | 75-100 | 50-75 | < 50         |
| Peat                       |     |     |     |              |
| Thickness (cm)             | < 60 | 60-140 | 140-200 | > 200        |
|                           | < 140 | 140-200 | 200-400 | > 400        |
| Thickness (cm), if there are mineral soil inserts |     |     |     |              |
| Maturity                   | Saprik | saprik, hemik | hemik fibrik | fibrik |
| Nutrient retention (nr)    |     |     |     |              |
| KTK klei (cmol c/kg)        | > 16 | ≤ 16 | - |              |
| Base saturation (%)        | > 35 | 20-35 | < 20 |              |
| pH H₂O                     | 6,0-7,0 | 5,5-6,0 | < 5,5 |              |
|                           | 7,0-7,6 | - |     |              |
| C organic (%)              | > 1,5 | 0,8-1,5 | < 0,8 |              |
| Toxicity (xc)              |     |     |     |              |
| Salinity (xn)              | < 1,1 | 1,1-1,8 | 1,8-2,2 | > 2,2        |
| Sodicity (xn)              |     |     |     |              |
| Alkalinity /ESP (%)        | - | - | - |              |
| Sulfidic hazard (xs)       |     |     |     |              |
| Sulfidic depth (cm)        | > 125 | 100-125 | 60-100 | < 60         |
| Erosion hazard (eh)        |     |     |     |              |
| Slope (%)                  | < 8 | 8-15 | 15-30 | > 30         |
| Erosion hazard             | very light | mild-moderate | severe | very severe |
| Flooding hazard            |     |     |     |              |
| Puddle                     | F0 | - | F1 | > F1          |
| High (cm)                  | - | - | 25 | < 25          |
| Duration (hari)            | - | - | < 7 | ≥ 7           |
| Land preparation (Ip)      |     |     |     |              |
| Rock on the surface (%)    | < 5 | 5-15 | 15-40 | > 40         |
| Rock out crops (%)         | < 5 | 5-15 | 15-25 | > 25         |

Tabel 1: Criteria of land suitability classification for cocoa [9]
3. Results and Discussion

3.1. Potential and Constraints of Smallholder Cocoa Plantation

The development of various leading agricultural commodities on Sebatik Island is very potential because it is supported by the adequate biophysical condition of dryland resources [4, 10]. The main commodity of plantation crops in this area is cocoa, generally in smallholder cacao plantations. The area of smallholder cocoa plantations in this region is more than 5,000 hectares, with productivity of less than 1 ton of dry cocoa [5]. The low productivity of these superior commodities is partly due to old plants, soil productivity which tends to decrease and disruption of pests and diseases.

Natural resources on Sebatik Island besides being used as a cultivation area, there are also protected areas. In addition to being used for cultivation areas for the development of annual crops also for annual crops. The main commodity of the annual crop in this area is cocoa, which is cultivated in several dryland development areas. However, land productivity for cocoa is still relatively low, caused partly because of land management that is not in accordance with the land suitability class. Factors limiting land quality and water availability need to get a touch of technological innovation to improve cocoa productivity, including through water conservation, nutrient management, utilization of organic matter and integrated farming system of crop-livestock [11,12,13,14,15].

Constraints on the development of cocoa on Sebatik Island, including economic, social and ecological aspects. From the ecological aspect, that is the degradation of land resources, especially soil damage due to erosion hazards and the absence of land and water conservation efforts, so that it can reduce the carrying capacity of the environment.

3.2. Characteristics of Natural Resources

The topography of Sebatik Island varies based on the shape of the relief, the slope and the height of the place from the sea level. The topography is mostly hilly to mountainous, with slopes of 15 to > 40% (Table 2).

| Topography   | Slope (%) | High Difference (m) | Area (% of total area) |
|--------------|-----------|---------------------|------------------------|
| Flat         | <1        | <1                  | 30.11                  |
| Rather flat  | 1-3       | <2                  | 2.09                   |
| Wavy         | 3-8       | 2-10                | 1.30                   |
| Bumpy        | 8-15      | 10-50               | 19.38                  |
| Little Hilly | 15-25     | 10-50               | 20.79                  |
| Hilly        | 25-40     | 50-300              | 25.16                  |
| (Settlement) | -         | -                   | 1.18                   |
| Total        |           |                     | 100                    |

Table 2: Topography and slope of Sebatik Island

The soil on Sebatik Island generally develops from sediment material and a small portion of river/marine deposits and volcanoes. This region has a soil moisture regime in the superior area (upland) classified as hicks with annual rainfall > 2000 mm, while the subordinate area (lowland) is classified as aquatic. Soil depth classes vary from shallow (<50 cm) to very deep (> 150 cm), but are generally dominated by deep classes (100-150 cm). The lands in this area are grouped into 3 Orders, namely: Entisols, Inceptisols, and Ultisols [4]. These types of the soil generally have low water holding capacity [16,17], so that if rainfall is abundant and not beneficial to plants, if groundwater holding capacity is low. Data on soil types on Sebatik Island, in Table 3.
Land suitability analysis is carried out by matching the quality of the land in each unit of the land map with the land use requirements for cocoa (crop requirements), in accordance with the land suitability criteria, published by the Center for Research and Development of Soil and Agro-climate [9]. Criteria of land suitability classification for cocoa in Table 1.

The land characteristics of each Land Map Unit (SPT) is represented by the type of land that has the largest area of the land association on Sebatik Island. Land suitability is a general description so that on suitable land, there can be inappropriate land. The actual land suitability classes and limiting factors for each land unit are in Table 4. In Table 4 it can be seen that the suitable land on Sebatik Island (S) for cacao plants is 20,581 ha (84.15%). Very suitable class (S1) is not available, because based on the criteria of land suitability class [9], from several land characteristics (slope, soil depth, soil pH, C-organic and CEC) nothing matches the class, especially slope criteria (none <8%). The main criteria used to compile a cocoa land suitability class on Sebatik Island is the slope. Fairly suitable class (S2) covering 7,616 ha (31.14%), marginal appropriate class (S3) covering 12,965 ha (53.01%), while unsuitable land (N) is 3,628 ha (14.83%).

In each land suitability class for cocoa (S2, S3, N) has a limiting factor. The suitability class of S2, the limiting factors are the availability of water (wa), erosion hazards (eh) and nutrient availability (nr). Class S3 the limiting factors are water availability (wa), oxygen availability (oa), erosion hazard (eh), nutrient availability (nr) and rooting condition (rc). In the not suitability class (N), the limiting factor is sulfidic hazards and limited rooting conditions (rc).

The results of the land suitability evaluation for cocoa indicate that land suitability consists of 3 classes, namely: S2 (quite suitable), S3 (marginal suitable), and N (not suitable). The area of S2 is 1.94% of the total area (473.36 Ha), with limiting factors for oxygen availability (blocked drainage), erosion hazards (low-moderate), root condition 50-75 cm, and sulfidic hazards (sulfidic depth 75-100 cm). The S3 class area is 88.36% of the total area (21.56 thousand Ha), with limiting factors for oxygen availability (blocked drainage), erosion hazards (low-moderate) and rooting condition 50-75 cm. While class N is 8.52% (2,089 Ha) with limiting factors is erosion hazards (slope > 40%), rooting condition (rough texture), and sulfidic hazards (sulfidic depth <40 cm).

| Ordo     | Grup            | Subgrup            |
|----------|-----------------|--------------------|
| **Entisols** | Quartzipsament | Typic Quartzipsament |
|          | Sulfaquents     | Typic Sulfaquent   |
|          | Endoaquents     | Sulfic Endoaquent  |
|          | Udorthent       | Typic Udorthent    |
| **Inceptisols** | Eutrudept      | Typic Eutrudept    |
|          | Dystrudept      | Oxic Dystrudept    |
|          |                | Typic Dystrudept   |
|          | Endoaquent      | Aeric Endoaquent   |
|          |                | Typic Endoaquent   |
| **Ultisols** | Hapludult      | Typic Hapludult    |
|          | Kandiudult      | Typic Kandiudult   |
|          | Paleudult       | Typic Paleudult    |

Table 3: Soil Types on Sebatik Island

3.3. Land suitability evaluation for cocoa
### Table 4: Actual land suitability classes and limiting factors in each unit of land for cacao on Sebatik Island

#### 4. Conclusion

Dryland is a natural resource that has a great opportunity for the development of community cocoa plantations on Sebatik Island. Most of the dry land is spread in the upstream watersheds that form a choppy to hilly area. In areas with high rainfall intensity, it can spur erosion and cause a decrease in the level of land productivity. Therefore, the use of Sebatik Island for smallholder cocoa plantations needs to be done according to suitability class.

In each land suitability class (S2, S3, N) has a limiting factor for cocoa. The suitability class of S2, the limiting factors are the availability of water (wa), erosion hazards (eh) and nutrient availability (nr). Class S3 the limiting factors are water availability (wa), oxygen availability (oa), erosion hazard (eh), nutrient availability (nr) and rooting condition (rc). In the not suitability class (N), the limiting factor is sulfidic hazards and limited rooting conditions (rc).
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