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Evaluation of the suitability of peat land for plantation commodities in Sambas District, West Kalimantan

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ABSTRACT

This research aims to determine the potential of peat land for the development of plantation crops which describes the potential of the land. This research is located in Sambas District, Sambas Regency, West Kalimantan. The number of soil sampling location are 10 sampling points. The initial activity of the program is collection of information about the status of peatland capability followed by a peatland suitability analysis to determine the types of plantation crops that are suitable for development. The data obtained include rainfall, temperature, topography, solum depth, water permeability, drainage conditions, erosion sensitivity, texture, C-Organic Content, Nitrogen, Phosphorus, Potassium, CEC and pH. The analysis of the suitability of the actual conditions of the land with the types of plantation crops, namely oil palm and rubber, is highly developed in Sambas sub-district because there are no growth limiting factors. Other plantation commodities that have the potential to be developed but have growth limiting factors (S3) are coconut, cloves, coffee, cocoa, tea, tobacco, cashew, nutmeg and vanilla which have 1 limiting factor, while cotton, melinjo and kapok commodities are categorized as highly inappropriate (N) with the heaviest limiting factor of water availability. The limiting factor of rainfall can be overcome through the creation of basins and drainage channels so that excess water in the land can be anticipated, while the improvement efforts that can be carried out on acid soils are the application of dolomite lime to increase the pH of the soil so that it is in accordance with the requirements of plant growth.

Keywords:
Crops, Land, Peaty, Potency, Suitability

1. Introduction

Sambas Regency is known for its abundant natural resources in Indonesia, including a diverse range of agricultural plants that strongly support resource utilization. This unique feature makes the area a potential hub for the development of various plant types, crucial for maintaining national food security in Indonesia. The plantation sector is particularly promising in Sambas Regency, offering an opportunity to improve the welfare of its people. As of 2021, the plantation area spans 109,646 ha and is primarily dominated by rubber, oil palm, and coconut [1]. Other commonly cultivated crops in the region include hybrid coconut, pepper, coffee, and cocoa.

The use of abandoned/degraded land has the potential to provide carbon conservation benefits, reduced GHG emissions, and economic benefits. However, further studies are needed to assess land status and suitability, technological readiness, costs, and institutions required to rehabilitate abandoned land into productive agricultural land [2]. According to data from the Badan Restorasi Gambut [3], peatlands in Sambas Regency cover a significant area of approximately 1,956 ha. The limited knowledge about cultivating plants in peat areas poses a challenge for many people in utilizing these peatlands for productive land. However, peatlands in Sambas Regency offer great potential for processing and improving people's welfare. Therefore, an urgent program is needed to identify the potential of peatlands for plantation cultivation in Sambas District. This program will provide essential information for utilizing peatlands, transforming them from marginal land to productive land suitable for crop cultivation, particularly plantation crops.

The objective of this study is to analyze the potential of peatlands for the development of plantation crop cultivation and to devise appropriate cultivation technology plans that can maximize crop yields. The research findings will shed light on the potential of peatlands for cultivating plantation crops and recommend suitable techniques to enhance plant growth on these lands. The program's output will provide valuable information on land potential, including soil characteristics, drainage requirements, and crop suitability, benefiting the community, government, and other stakeholders interested in this area of study.

2. Methods

The research is a survey conducted in Sambas District, Sambas Regency, West Kalimantan. The initial activity involved collecting information on the capability status of peatland. This was followed by a peatland suitability analysis to determine the types of plantation crops suitable for development on the sampled lands. The sampling points were determined by gathering information from the community and relevant government sources, specifically focusing on the distribution map of peatlands in Sambas District.

Data was collected using two methods: direct data collection in the field and soil analysis. In the field, data was collected through measurement activities and interviews with farmers. Soil samples were taken from the land and sent to the Soil Laboratory of the West Kalimantan Agricultural Technology Assessment Center (BPTP) for analysis.

Directly collected field data includes observations of the slope level (topography), solum depth, water permeability, drainage conditions, and sensitivity to erosion. These observations were conducted to assess the land's suitability for cultivation. Additionally, climate data collection is necessary to analyze the land's capability for specific crops or agricultural activities. The collected climate data will include average temperature, humidity, and rainfall information.

Soil sampling for this study involved obtaining an overview of land capability in relatively homogeneous areas or plots of land. The number of soil samples was adjusted according to the area or plot size. Sampling points were chosen randomly to ensure representation of all peatland soils in Sambas District. A total of 10 soil sampling points were selected randomly for this study.

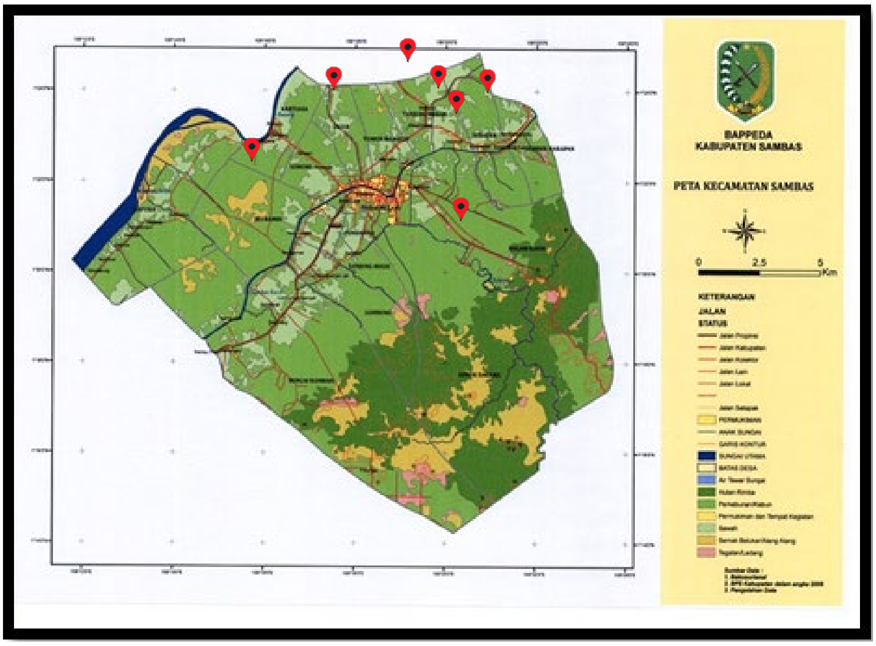

Figure 1. Research sampling location

The soil samples collected are from the rhizosphere, which is located at a depth of between 0 and 50 cm from the surface. These samples are obtained by taking a mixture of samples from various locations within the same land or plot, using random, zigzag, or diagonal sampling patterns. Each area or plot of land is represented by one composite soil sample. The collected soil samples are then packed into containers and sent to the laboratory for analysis. In the laboratory, the soil is analyzed to determine the type of texture (using 3 hydrometer fractions), C-Organic content (via spectrophotometry), Nitrogen (using the Kjeldahl method), Phosphorus (using the Olsen method), Potassium (using the Morgan-Wolf method), as well as to assess soil salinity and acidity levels (pH H_2O). The soil analysis for this study was conducted at the West Kalimantan Agricultural Technology Assessment Center (BPTP) Laboratory.

The process of evaluating land and determining its use is carried out through several stages. This involves compiling land characteristics and assessing how well the actual conditions of the land meet the requirements for plant growth. The suitability of the selected land is used by researchers or land managers to determine the appropriate land use for plantation crops. Land characteristics include: Topography, solum depth, water permeability, drainage conditions, erosion sensitivity, texture type, C-Organic content, Nitrogen, Phosphorus, Potassium, CEC, and pH. Climate data, obtained from the West Kalimantan Central Statistics Agency (BPS) data (2021), consists of annual average rainfall and air temperature.

The analysis of the capability and suitability of peatlands will be determined using a simple boundary method, which involves comparing the land characteristics with predetermined criteria. The requirements for plant growth, as outlined by Djaenudin et al. [4], encompass various factors such as soil conditions, nutrient availability, and environmental factors. After collecting the data on land characteristics, the land evaluation process is conducted by researchers or land evaluators. This involves manual comparison of average values for each parameter, obtained from the

7 sampling locations, to gain an overview of the actual conditions at the research locations. The land suitability assessment categorizes the land into potential classes and subclasses, based on the presence of limiting factors such as soil properties and drainage conditions. The land evaluation results provide information on both the actual conditions (actual land suitability) and the potential conditions (potential land suitability) of the land.

The land suitability information obtained in this study serves as valuable information for various stakeholders, including government agencies, farmers, and agricultural development programs, to support sustainable agricultural development in Sambas Regency, particularly in the context of the regional superior commodity development program.

3. Results and Discussion

3.1. Land Suitability for Several Types of Plantation Crops

The suitability of peat land in Sambas District for various plantation crops can be assessed by conducting a land quality analysis that considers the characteristics of the research location, including climate and soil conditions. The actual land suitability classification is a system that categorizes the land suitability levels based on the existing characteristics, without considering the required input such as nutrient amendments or other treatments. Actual land suitability refers to the suitability of the land based on its physical characteristics before any treatment or interventions are implemented to address the limiting factors. Potential land suitability, on the other hand, reflects the projected suitability of the land after implementing efforts to improve its quality, particularly addressing the limiting factors. Researchers or land evaluators compare the land against the requirements for growing plantation crops to determine its suitability class after addressing the limiting factors.

The level of land suitability is categorized into different orders based on the severity of the limiting factor. The appropriate order (S) includes three classes: very appropriate (S1), suitable (S2), and marginally appropriate (S3). Land that is unsuitable for cultivated plants due to severe limiting factors is categorized as Order N. Land categorized as Order N is characterized by limiting factors that are exceptionally challenging to address or cannot be effectively overcome. Land suitability analysis in this study follows the method proposed by Djaenudin et al. [4], which evaluates land suitability based on specific criteria and parameters. The land suitability analysis considering plant growth requirements indicates that the heaviest limiting factors for land suitability are nutrient retention and water availability.

Determining the improvement efforts should consider the land characteristics that influence its quality. Generally, limiting factors associated with the physical characteristics of the soil can be addressed through appropriate management practices. However, limiting factors related to climatic characteristics often require costly efforts and may be impossible to completely mitigate. The extent of the improvement efforts depends on the severity of the limiting factors present in the land, which determines the associated costs. The assessment of land suitability for various plantation crops initially involved comparing the actual climatic conditions of the land with the specific climatic requirements of the plants. This approach helps identify suitable plant types that can thrive in the actual climate of the research area.

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According to Djaenudin et al. [4], the assessment of land suitability by comparing the actual conditions of the land with plant growth requirements revealed several types of plantation crops with development potential (Table 1). The heaviest limiting factor observed in the land was the nutrient retention capacity, specifically the acidic soil pH recorded at the seven sampling locations. Soil acidity is an indicator of soil fertility as it affects nutrient availability [5]. The analysis showed a correlation between high organic carbon (C) content, measured at 4.4%, and the low pH of the sampling area. This suggests that the activity of organic matter decomposition by microorganisms may contribute to soil acidity. The acidic soil pH is a result of the decomposition process and metabolic activities of microorganisms. The limiting factor of soil acidity at the sampling locations indicates a suitability class of S3, which falls under the marginally suitable category. To meet the requirements for plant growth, efforts are necessary to improve the land's capability to reach a higher suitability class of S2 (suitable).

Table 1 shows the land suitability of several types of plantation crops that can be cultivated having more than 1 limiting factor. Based on the table it can be seen that in general the research location has the potential to be used as land for the development of certain plantation crop commodities, namely oil palm and pepper which are categorized as very suitable based on the results of land evaluation. The results of this study also show that the heaviest limiting factor is the ability to retain nutrients, namely the acidity of the soil and the availability of water at the study site which is still a major problem for several types of plantation crops.

Oil palm and pepper are the most suitable types of plants to be cultivated at the sampling location because these are do not have growth limiting factors. Meanwhile, other plants such as coconut, rubber, cocoa, tobacco, sugar cane, quinine and vanilla have a limiting factor, that is nutrient retention (pH) which in the marginal category (S3). Another growth limiting factor with marginal criteria (S3) is the water availability which it affects the growth of coffee, tea, sugar cane, cashew nuts, quinine, nutmeg and is not suitable (N) for melinjo, cotton and kapok plants. Very high rainfall intensity at the research location causes the amount of water in the soil to be very large, which becomes a limiting factor for these plants. Cloves and quinine have a temperature limiting factor (tc) where the temperature of the research location is high level, that is inhibiting the plants growth that can grow optimally at lower temperatures.

Table 1. Land suitability for several types of plantation crops

Suitability Criteria		Coconut	Rubber	Palm oil	Arabica coffee	Robusta coffee	Cocoa	Clove	Tea	Tobacco	Sugarcane	Cashew	Melinjo	Cotton	Kapok	Quinine	Pepper	Nutmeg	Vanili
Temperature (tc) Average	26,9	S1	S1	S1	S1	S1	S2	S3	S1	S1	S1	S1	S1	S1	S1	S3	S1	S2	S2
Water availability (wa) **Rainfall (mm)**	3397	S2	S2	S2	S3	S3	S2	S1	S3	-	S3	S3	N	N	N	S3	S1	S3	S2
O2 availability (oa): **Drainage**	good	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Rooting medium (rc): a. **Texture**	Ah	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
b. **Soil depth**	75	S2	S2	S2	S2	S2	S2	S2	S1	S3	S2	S1	S1	S1	S2	S2	S2	S2	S2
Nutrient retention (nr) : a. **KTK (cmol.kg^{-1})**	0,4	-	-	S2	S2	S2	S2	S2	S1	S2	PS2	S2	-	S2	S2	S2	S2	S2	S2
b. **pH H2O**	4,2	S3	S3	S2	S2	S3	S3	S2	S2	S3	S3	S2	S3	S3	S3	S3	S2	S2	S3
c. **C-organic (%)**	4,4	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Erosion hazard (eh): a. **Topography (%)**	Flat	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
b. **Erosion hazard**	No	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Flooding hazard (fh): **Flooding**	F0	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Limiting Factors		**S3nr**	**S3nr**	**-**	**S3wa**	**S3wa nr**	**S3nr**	**S3tc**	**S3wa**	**S3tc nr**	**S3wa nr**	**S3wa**	**S3nr Nwa**	**S3nr Nwa**	**S3nr Nwa**	**S3tcwanr**	**-**	**S3wa**	**S3nr**

3.2. Rainfall Limiting Factor

Rainfall refers to the quantity of rainwater that falls on a flat surface without evaporation, seepage, or flow. Rainfall is generally written in millimeters (mm) [6]. Based on the rainfall data obtained from BPS [1], it is evident that the location experiences exceptionally high rainfall, measuring 3397 mm. Such conditions generally do not favor the growth of certain plantation crops. This is because high rainfall has the potential to cause land inundation, delays in the flowering process, and an increased prevalence of pests and diseases. High rainfall triggers the development of pests such as fruit flies, thereby reducing fruit production and quality [7]. The presence of diseases caused by rainfall can disrupt plant growth and directly affect crop yields [8]. Additionally, the high rainfall levels limit assimilate production due to reduced sunlight energy reaching the plant canopy as a result of lower irradiation intensity.

High rainfall intensity is a limiting factor for climate elements that have a significant effect on crop production. Rainfall intensity generally determines crop yields [9]. Excessive rainfall has the potential to cause flooding, negatively affecting plant metabolism and leading to reduced production and crop failure [10]. Generally, plantation crops require a lot of water to support their growth and development but are intolerant of long-term inundation. To address the limiting factor of inundation, efforts to upgrade the research location land from class S3 to S2 can be made by improving drainage systems to prevent inundation. Failure to carry out respiration can result in plants becoming deficient in ATP needed in metabolic processes. This has an impact on decreased growth and development of organs. Rainfall limiting factors can be overcome by making basins and drainage channels so that excess water in the land can be anticipated [11].

3.3. Nutrient Retention Limiting Factor

The problem of soil acidity is a common problem found in fields in West Kalimantan. This is due to the characteristics of the Kalimantan region, especially in Sambas District, which is dominated by natural peatlands which are used by the community for plant cultivation activities. Peatlands in the region, known for their low pH levels, retain this characteristic for an extended period, even after cultivation, as they are essentially immature peatlands undergoing the maturation process. An acid reaction in the soil which causes a low pH because the soil is deficient in Calcium (CaO) and Magnesium (MgO) due to high rainfall. The high intensity of rainfall causes the soil to become acidic due to the leaching process of nutrients, poor drainage and long-term inundation. Excess nutrients such as Al (aluminum), Fe (iron), and Cu (copper) are always found in soils with low pH. The decomposition of organic matter, particularly in peat soils, is a significant factor contributing to soil acidity [12].

Soil pH determines the efficiency of absorption of nutrients by plants. Low soil pH causes plants to be unable to absorb N, P, K, and other nutrients needed. According to [13], elements N, P and K are easily absorbed by plants in the pH range between 5.5 and 9.0. Moreover, low pH levels enhance the availability of toxic elements such as aluminum, which can be harmful to plants and bind phosphorus, thereby reducing its availability for plant uptake [14]. The effect of low pH affects the growth of plantation crops because under acidic pH conditions, nutrients will be bound by binding minerals such as Al and Fe. As a result of interfering with the process of absorption by the roots resulting in plants experiencing nutritional deficiencies. Low pH results in the accumulation of toxic ions such as Al and Fe which can poison plants. Improvement efforts that can be carried out on acid soils are the provision of dolomite lime to increase soil pH so that it is in accordance with the requirements of plant growth.

3.4. Nutrient Content of Sampling Location

Land capability on other parameters can be increased from class S2 (appropriate) to class S1, namely the depth of the soil which is generally known to have an average depth of 75 cm. depth of more than 75 cm generally has a clay texture so it is not suitable for root development. Clay has a low ability to store minerals so that the soil depth parameter in this study refers to the depth of clay-textured soil. In addition, clay-textured soil has fine pores so that its aeration ability is not good. Considering the fast growth of horticultural plants, nutrient availability plays a crucial role in supporting their growth. Soil depth plays an important role in supporting the spread of roots to get nutrients. An alternative approach to elevate the class from S2 to S1 involves implementing tillage to address the limiting factor of soil depth. This aims to enlarge the pores and loosen the soil in order to increase the ability of aeration and support the penetration of plant roots in the soil thereby increasing the reach of the roots to obtain nutrients.

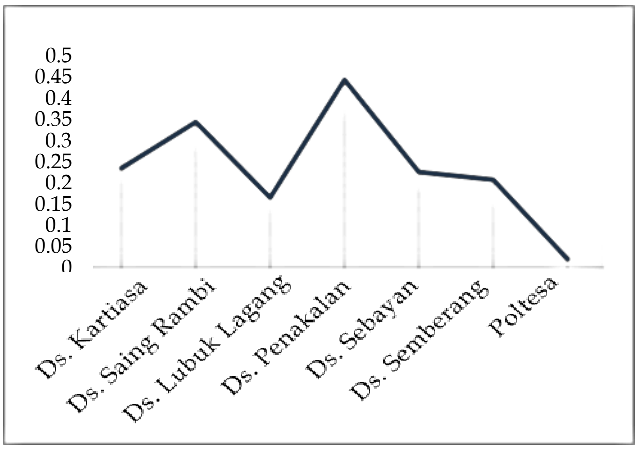

Figure 3. Nitrogen content (%) in research locations

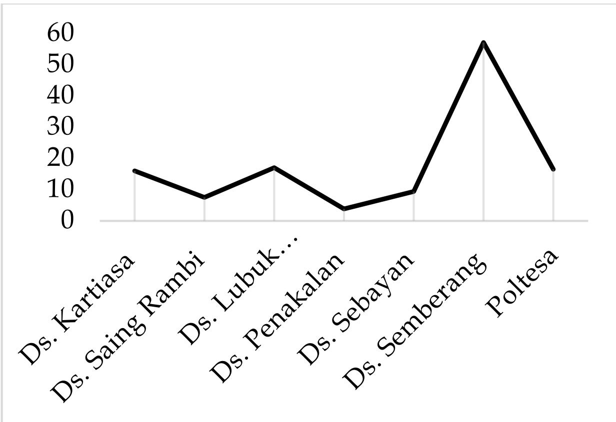

Figure 4. Phosphorus content (ppm) in research locations

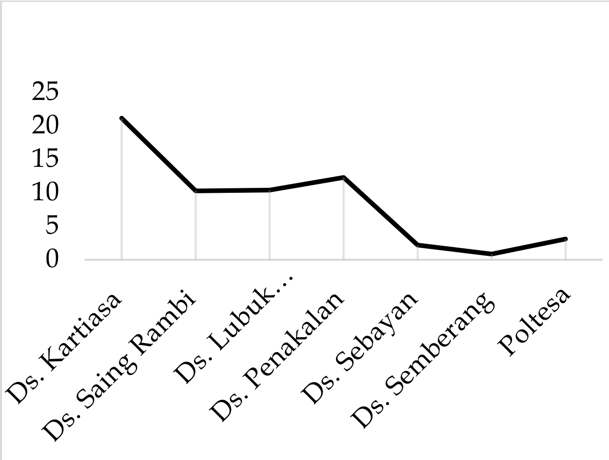

Figure 5. Potassium (K) content (mg/100g) in research locations

Analysis of soil fertility levels based on the N, P and K content of the soil samples in the study locations in Figures 3, 4 and 5 refers to the criteria for determining soil fertility according to [15] indicating that in general Sambas District has low to moderate soil fertility. The content of nitrogen elements (Figure 3) in the villages of Lubuk Dasa and Poltesa showed low nitrogen content, while other locations showed moderate concentrations of nitrogen. The analysis of phosphate content using the Olsen method (Figure 4) revealed that the sample from the village of Penalakan exhibited very low phosphate content. Saing Rambi and Sebayan villages displayed moderate P content, while other locations showed high phosphate levels. The results of the analysis of K content (Figure 5) at 3 locations, namely Sebayan Village, Seberang Village and Lahan Poltesa, showed very low K concentrations, while in Saing Rambi Village, Lubuk Dagang Village and Penalakan Village showed low K content, whereas in the Kartiasa Village location has a moderate concentration of K.

Table 2. Criteria for soil fertility based on the nutrient content of N, P, and K

Nutrient	Fertility criteria				
	Very low	Low	Medium	High	Very high
N (%)	< 0.1	0.1-0.2	0.21-0.5	0.75	0.75
P_2O_5 Olsen (ppm [P])	<5	5-10	11-15	16-20	>20
K_2O HCl 25% (mg.100 g^{-1})	<10	10-20	21-40	41-60	>60

Source: Evianti et al. [15]

Low soil fertility is generally characterized by very acidic soil pH, very low to low organic C and total N content, very low to medium P-total soil, very low to low total soil K and low to moderate soil base saturation. Therefore, generally the limiting factor for plant growth, especially plantation types, is found in the ability to retain nutrients [11]. The main role of the element Nitrogen is to stimulate vegetative growth; constituents of leaf chlorophyll, fat and protein. Nitrogen is absorbed by plants in the form of ammonium (NH^{4+}) and nitrate (NO^{3-}). Phosphate plays a vital role in stimulating root growth, facilitating the development of the root system through cell division, accelerating the initiation of flowering, fruit and seed ripening, increasing fruit formation, and contributing to cell nucleus, fat, protein, and disease resistance. Phosphate rock and SP36 are able to reduce Al-P, Fe-P, and Ca-P so that they can be absorbed by plants [16]. Plants absorb phosphate from the soil in the form of H_2PO^{4-} and HPO^{4-}. Phosphate in the soil is absorbed by plants in the form of H_2PO^{4-} and HPO^4. Meanwhile, Potassium is absorbed by plants in the form of K^+, especially in young plants which plays an important role in cell turgidity due to osmotic pressure [13].

4. Conclusion

The suitability of actual land conditions with types of plantation crops, namely oil palm (*Elaeis guinensis*) and pepper (*Piper* sp.) are the most suitable types of plants to be cultivated at the sampling location because these are do not have growth limiting factors. Other plants such as coconut (*Cocos nucifera*), rubber (*Cocos nucifera*), cocoa (*Theobroma cacao*), tobacco (*Nicotiana* sp.), sugar cane *(Saccharum officinarum),* quinine *(Anacardium occidentale)* and vanilla (*Vanilla planifolia*) have a limiting factor, that is nutrient retention (pH) which in the marginal category (S3). Another growth limiting factor with marginal criteria (S3) is the water availability which it affects the growth of coffee (*Coffea* sp.), tea *(Camelia sinensis)*, sugar cane *(Saccharum officinarum)*, cashew nuts *(Anacardium occidentale)*, quinine *(Cinchona succirubra),* and nutmeg (*Myristica fragrans*) and is not suitable (N) for melinjo (*Gnetum gnemon*), cotton and kapok (*Ceiba petandra*).

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