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Mapping of cropland suitability at marginal area Situbondo district

Mapping of cropland suitability at marginal area Situbondo district

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Abstract. Marginal land development in Situbondo Regency has not yet received special attention from farmer as the farmer-enterpreneur, so that the efforts made by stakeholders have not yet gotten maximum results. Therefore, increasing awareness and understanding of the development and use of marginal area is needed. The objectives of this study are: 1) knowing the land characteristics of crops commodities at marginal land and (2) mapping the suitability of cropland at marginal land. The locations of the study are Jatibanteng and Sumbermalang Subdistricts with the consideration that the subdistrict is the area where the majority of rice fields are dry and marginal area in Situbondo Regency. The research method uses an analytical approach. The data collection method is using secondary data, which is available statistical data that has been published by BPS and primer data. The data analysis method uses SRTM (Shuttle Radar Topography Mission) and soil chemical analysis. The results showed that of (1) the land characteristics can be seen from soil chemical analysis including: a) Phosfor content of land ranged from 28,06-84,28 me/100g which was dominated by high status; b) Potassium value of land ranged from 16.95-59.96 me/100g which was dominated by moderate status; c) Organic matter content of land ranged from 1.75-3.39% which was dominated by medium status; d) Cation Exchange Capacity (CEC) value of land ranged from 14.76 - 37.03 me/100g which was dominated by the high status; and e) Base Saturation in Jatibanteng Subdistrict was classified as low to moderate, ranged from 30.39% - 50.10% and Sumbermalang subdistrict ranged from 20.15% - 48.62%. Provision of organic material is a way that can be applied to increase the value of BS, because organic matter affects soil properties such as its physics and chemistry. (2) Meanwhile the the second objective was found that: a) around 35% of Jatibanteng Subdistrict was in the S1 (Highly Suitable) category; on the other hand, Sumbermalang Subdistricts was in the S2 (Moderately Suitable) and S3 (Marginal Suitable) categories for the rice field suitability, b) class suitability of corn in the study area was included in the more dominant of S2 (Moderately Suitable) category reaching almost 85% of the land areas, and c) cassava plants had an S1 (Highly Suitable) suitability class dominated by Jatibanteng Subdistrict which was almost 50% of its areas in Sumbermalang Subdistrict with the suitability of S2 (Moderately Suitable) and S1 (Highly Suitable).

1. Introduction

Regional development in Situbondo Regency is part of the process of developing a production growth center. The development of this production growth center has links between regions in all districts in Situbondo Regency. To support this, it is necessary to map land suitability and intensification of

agricultural commodities, especially food crops in Situbondo Regency so that the development resources can be used efficiently. Development of the food crop subsector has a very strategic role because it can support most of the population. Based on statistical data of Situbondo [2], the potential for food crop production can be seen in the following table.

Table 1. Land Area, Production, and Productivity of Food Crops in Situbondo Regency in 2019

No.	Commodity	Land Area (Acres)	Production (Ton)	Productivity (Ton/Acres)
1.	Rice	5,594	292,568	5.56
2.	Corn	49,671	248,467	5
3.	Cassava	388	8,719	22.47
4.	Green beans	79	159	2.01
5.	Peanuts	508	636	1.25
6.	Soybeans	25	31	1.24

Management of agricultural resources through an efficient farming system must consider the sustainability and preservation of natural resources and must be able to produce a highly competitive production. But the development of marginal land in Situbondo Regency has not received any special attention from farmers as actors in farming yet, so that the efforts made by stakeholders have not yet gotten maximum results. Therefore, improvement in awareness and understanding of the development and use of marginal land especially for food crops is needed. Because food crops in addition to meeting people's consumption needs also play a role in providing industrial raw materials.

In Situbondo, marginal land is often found on dry land. These marginal lands are scattered in several regions where the prospects are good for agricultural development but currently not being managed properly. Farming practices nowadays are still paying less attention to the rules of conservation, resulting in deterioration of land fertility caused by erosion [3]. Based on it, the objectives of this research are as follows: (1) knowing the land characteristics of crops commodities at marginal land and (2) mapping the suitability of cropland at marginal land.

2. Reseach Methodology

The research was conducted in Jatibanteng and Sumbermalang Sub-districts, since both of these districts were mostly dry and marginal land in Situbondo Regency. The research uses an analytical approach method [9]. The data collection was done by using secondary data and primary data. The data analysis was done by using SRTM (Shuttle Radar Topography Mission) and chemical analysis. Soil chemical analysis was carried out on several variables that determine the level of soil fertility to draw a conclusion on classification of research area suitability for the assessment of soil fertility status. The analysis carried out was soil chemical analysis as follows: a) C-Organic Analysis (Kurmis Method), b) P-Total and K-Total Analysis (25% HCL extract), and c) CEC and BS Analysis (NH_4OAc method pH 7.0). Flow of the research stage can be seen in image below.

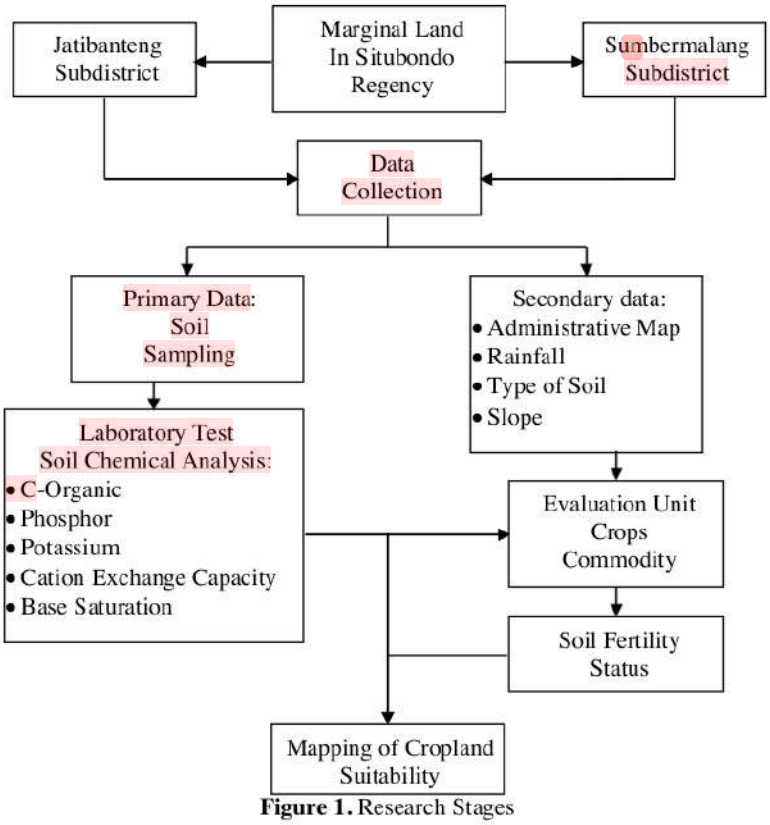

Figure 1. Research Stages

3. Result and Discussion

3.1 Land Characteristics of Food Crop Commodities in Marginal Land

The results of soil chemical analysis carried out in Jatibanteng and Sumbermalang Sub-Districts, Situbondo Regency to determine the level of soil fertility and to determine the suitability status cropland in the area being researched. The soil chemical analysis tested included Phosphor (P), Potassium (K), C-Organic, Cation Exchange Capacity (CEC) and Base Saturation (BS).

3.1.1 Phosphor (P)

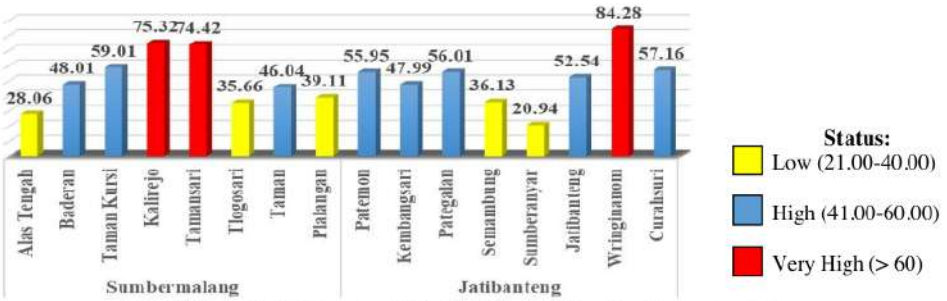

Figure 2. P (Phosphor) Nutrient Content in The Researched Area

Figure 2 yields that the P_2O_5 content of paddy soils in the researched ranged from 28.06 me/100g - 84.28 me/100g and it was classified as low to very high status which was dominated by high status. In this research case, it was dominated by high status. The availability of P nutrients is influenced by several factors such as pH, main material, soil organic matter and clay mineral fixation. Alluvium soils are poor in P, but rich in exchanged bases such as K, Ca, Na, and Mg [5]. To increase the phosphorus nutrients, the soil pH must be in the range of 5.5 - 7.0 (optimal pH for P availability). Low pH (too acidic) and high pH (too alkaline) will cause the phosphorus nutrients to be easily retention [11]. Addition of organic matter and administration of phosphate solvent microorganisms can also increase the availability of Phosphor. The high P content in the soil is also dominantly affected by the main material. The P nutrient content in the researched area can be seen in the following figure.

3.1.2 Potassium (K)

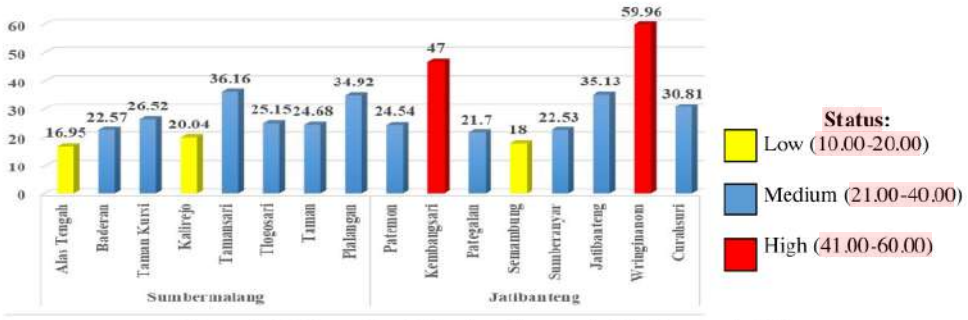

Figure 3. K (Potassium) Nutrient Content in The Researched Area

High Potassium Distribution was found in areas with the main material originated from volcanic ash of Ringgit mountain which was ultra-basic to intermediate. The main material was rich in exchanged bases such as K, so that saturation of cations can be exchanged in most of the paddy soils in Situbondo, which was classified as high. From Figure 2, it can be seen that the K_2O value of land in the researched area was in the range of 16.95 me/100g - 59.96 me/100g, which was included in the low to high status and was dominated by moderate status. The low K content of the soil was caused by leaching, erosion and straws that had accidentally transported when harvesting. The low K content in the area was assumed to be caused by frequent erosion and landslides in the area. The soil particles in the erosion area was accidentally transported, so that the top-soil layer as a gathering place for organic matter was reduced.

3.1.3 C-Organic

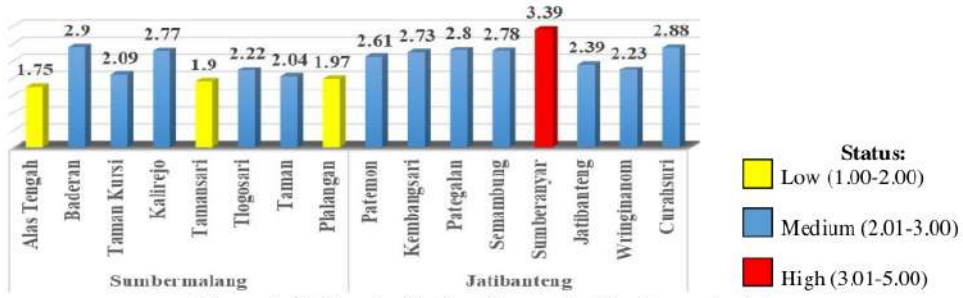

Figure 4. C-Organic Nutrient Content in The Researched Area

In general, organic matter in the soil accumulates in the upper layers, at low status. The content of organic matter was also suspected from a deep land dredging, due to frequent tillage, for example, the use of tractors or other land plow tools. The deeper the tillage was carried out, the lower the remaining organic matter was in the soil [6]. The organic matter content of soil in the researched area was in the range of 1.75% - 3.39% with low to high status dominated by medium status. High status was in the subdistrict of Jatibanteng, Sumberanyar Village. Organic matter can increase or remain available in the soil due to the high soil clay content [7].

3.1.4 Cation Exchange Capacity (CEC)

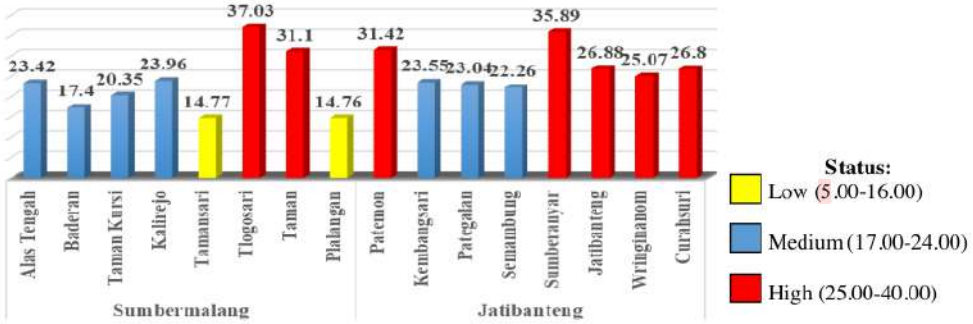

Figure 5. CEC Nutrient Content in The Researched Area

CEC is a fixed unit of the soil because it depends on the following: 1) the clay content of the soil; 2) organic matter content which is always changing [10]. Clay minerals have a major role in improving CEC in the soil. This happens because most of the negative charge of the soil is responsible for increasing the CEC. The silica layer possessed by the clay contains a negative charge so that it can attract cations in the soil. CEC values in the researched area was in the range of 14.76 me/100g - 37.03 me/100g, which was included in low to high status dominated by the high status. The high value of CEC in the researched areas that were dominantly having organic matter values in moderate to high status. This means that the farmers in these areas are always maintain the availability of organic material into the soil. Addition of organic matter to the soil surface will increase the CEC [1].

3.1.5 Base Saturation (BS)

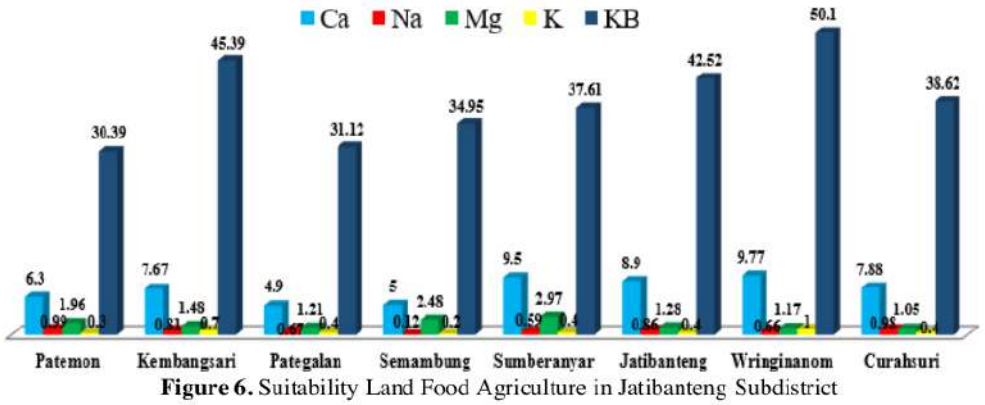

Figure 6. Suitability Land Food Agriculture in Jatibanteng Subdistrict

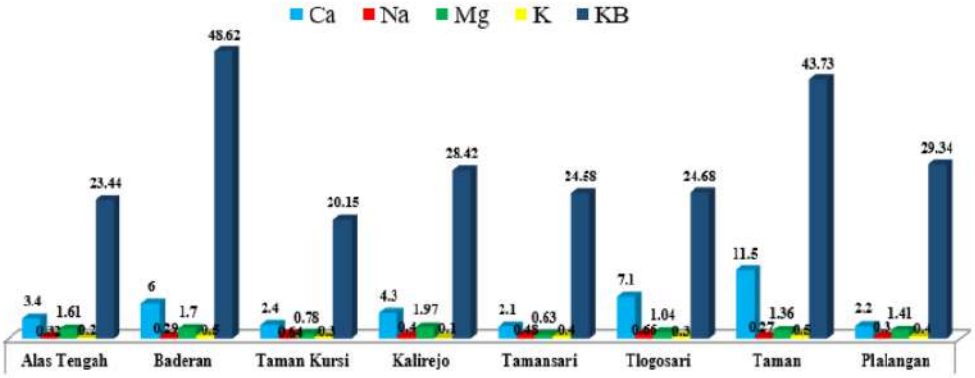

Figure 7. Suitability Land Food Agriculture in Sumbermalang Subdistrict

The research was done in a relatively high-altitude area, which means that it is more prone to erosion, so that the base cations will be easily lost. The altitude of the place affects the magnitude of the BS value, because the base cation is a nutrient that is easily washed away by water flow [15]. High and low percentage of base saturation in the researched area is closely related to organic matter content, including base cations such as Ca, Mg, K and Na [8]. BS in Jatibanteng Subdistrict was classified as low to moderate with the value of 30.39% - 50.10% and Sumbermalang Subdistrict ranged from 20.15% to 48.62%. Provision of organic material is a way that can be applied to increase the value of BS, because organic matter affects soil properties such as its physics and chemistry. In relation to the physical properties of soil, organic matter has a role in forming granulation and is very important in the formation of stable soil aggregates [1].

3.2 Land Suitability Map on Food Crop Commodities in Marginal Land

Soil fertility status can be taken into consideration in improving the amount of organic matter. Returning crop residues to the land or adding compost from livestock manure are some of the right ways to replace the lost soil's nutrients [16]. The evaluation of soil fertility is intended to assess the status and determine the main obstacles to soil fertility namely the status of low, medium and high.

Table 2. Status Suitability Land Food Agriculture in in The Researched Area

Status	Subdistrict	Village	P_2O_5	K_2O	C-Org	CEC	BS
Low	Sumbermalang	Alas Tengah	M	L	L	M	L
		Taman Kursi	H	M	M	M	L
		Kalirejo	H	L	M	M	L
		Tamansari	H	M	L	L	L
		Tlogosari	M	M	M	H	L
		Plalangan	M	M	L	L	L
	Jatibanteng	Patemon	H	M	M	H	L
		Pategalan	H	M	M	M	L
		Semambung	M	L	M	L	L
Medium	Sumbermalang	Baderan	H	M	M	M	M
		Taman	H	M	M	H	M
	Jatibanteng	Kembangsari	H	H	M	M	M
		Sumberanyar	M	M	H	H	M
		Jatibanteng	H	M	M	H	M
		Curahsuri	H	M	M	H	M
High	Jatibanteng	Wringrinanom	H	H	M	H	M

From the table above, it can be concluded that the land suitability status for food crops in the researched area was at a low, medium and high status. High status was in Jatibanteng Subdistrict, precisely in the Wringinanom Village. Land use requirements for rice, corn and cassava that were used in this research were the temperature, water availability, root media, nutrient retention, available nutrients, and the danger level of erosion. Each land use has evaluation results with varying wide of area.

The limiting factor that causes the fertility status to be low is the C-Organic. The low C-Organic is caused by the land management such as the lack in returning the leftover of the harvest to the soil. This can be solved through the addition of soil organic matter. Addition of organic matter can increase the population of soil microorganisms (bacteria, fungi and toadstool). The mycelia or fungal hyphae and toadstools are able to unite soil grains into aggregates, while bacteria act like cement that unite the aggregates [15]. So, the more stable the soil aggregate, then the soil erosion is expected to be reduced.

In general, the limiting factor that causes the status to be moderate in the researched area was due to the low value of BS (Base Saturation). The low in BS was assumed to be caused by the relatively high Na content. High Na content is not only damaging the soil structure, but also making the pH of the soil to be alkaline so that the cations become not optimal. Adding organic matter to the soil is one of the ways to increase the value of base saturation. The simple end result of an overhaul of organic material includes base cations such as Ca, Mg, K and Na. Increasing the exchanged cations can be done by giving the organic fertilizer containing Ca, Na, Mg, and K proportionally (balanced).

The intensive addition of organic material into the soil must always be done so that the soil fertility status remains at high status. For example, returning the crop residues/leftover to the land, as well as the addition of compost from livestock manure is one of the appropriate ways in replacing the lost nutrients. According to [7], the addition of organic matter to the soil surface will increase the CEC.

Soil in the researched area was formed from the main material of klei sediment, klei alluvium sediment, sand sediment, andesite tuff, klei stone, and limestone. The lands of the researched area are classified according to Soil Taxonomy [14] into six orders, namely Alfisols, Entisols, Inceptisols, Mollisols, Ultisols, and Vertisols. The distribution of slopes suitable for the development of rice, corn, and soybean plants is 0-15% slope with flat to undulating landforms. The physical problems of land for areas that are not suitable can be overcome with technology, as long as the technology is safe for the environment with rational costs such as making terraces. Climate and temperature are important requirements in evaluating the land. Temperature is an important factor for plants growth and development. According to [12], in wet climates, the climate factor that affects erosion is the rain. The amount of rainfall, intensity, and rainfall distribution determine the strength of rain dispersion to the soil, the amount and strength of surface runoff and the level of erosion damage that occurs in addition to the slope and texture factors.

3.2.1 Land Suitability of Rice Plants

Rice plant is a type of food crops that has an important role for people's lives. One of the challenges that arise in rice cultivation is a decrease in land productivity. Continuous land use can reduce the function of land in supplying various nutrients in the soil.

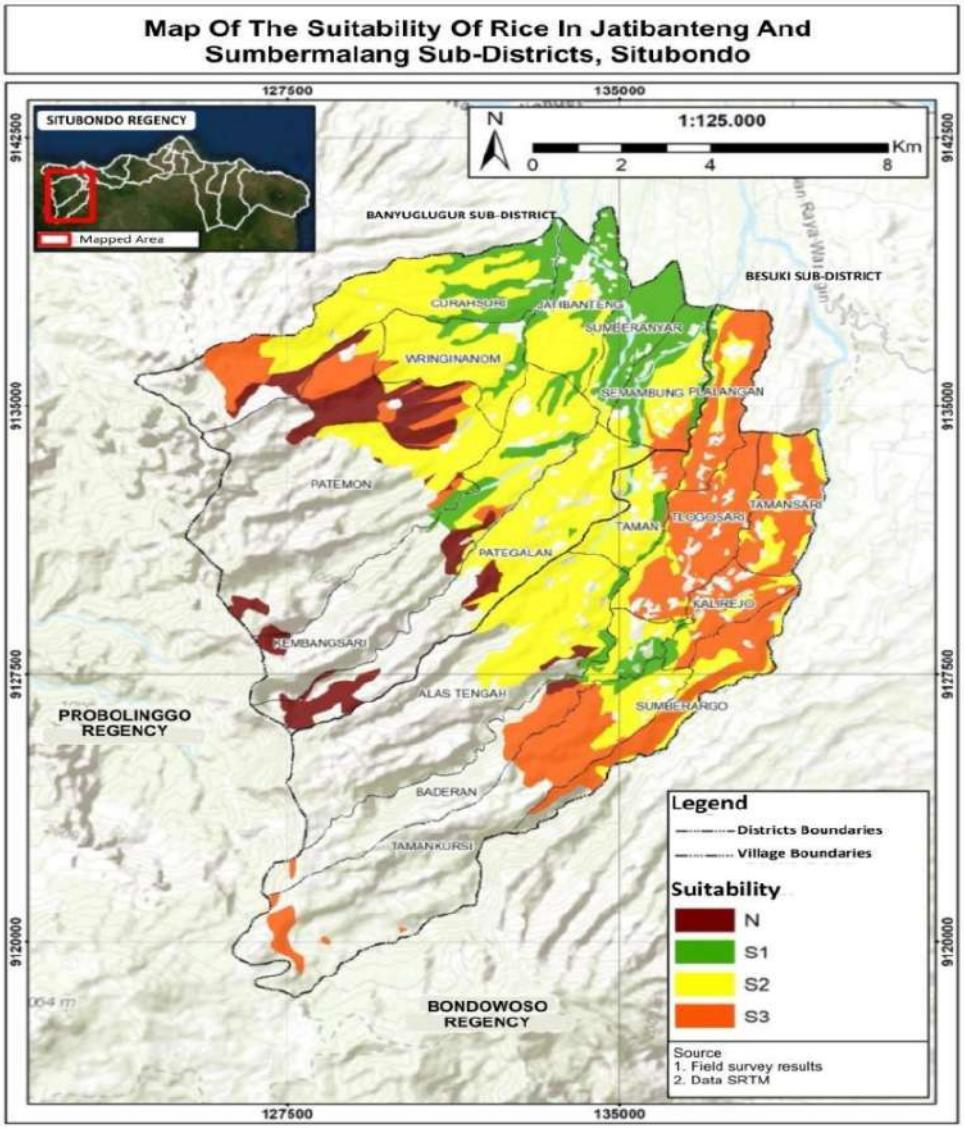

Figure 8. Suitability Land of Rice Plants in The Researched Area

From Figure 8, it can be explained that around 35% of Jatibanteng Subdistricts are in the S1 category, Sumbermalang Subdistrict to be categorized as S2 and S3 for land suitability of rice plants. Only a small portion in the northern region that are in the S1 category so that not many people are growing rice plants in Sumbermalang Subdistrict. Whereas Jatibanteng Subdistrict is very suitable for rice plants cultivation because the area is in the S1 category.

Table 3. Indicator Land Suitability of Rice Plants

Indicator	Category Land Suitability				Source
	S1	S2	S3	N	
CEC	>16	≤16			Djaenudin dkk, 2011 [4]
BS	>40	30-40	<30		Sareh & Rayes, 2019 [18]
C-Organic	>1.2	0.9 – 1.2	<0.9		Sareh & Rayes, 2019 [18]
Potassium	>15	2-15	<2		Sareh & Rayes, 2019 [18]
Slope	<3%	3-8%	8-25%	>25%	Djaenudin dkk, 2011 [4]
Phosphor	>15.3	4.9-15.3	<4.9		Sareh & Rayes, 2019 [18]

Information : Category S1 Highly Suitable, Category S2 Moderately Suitable, Category S3 Marginal Suitable, Category N Currently Not Suitable

The C-Organic content in the researched area is in a very high category in Jatibanteng Subdistrict, Sumberanyar Village. Rice plants can grow optimally if the content of C-Organic in the soil > 1.2. Rice plants have a limiting factor that needs to be considered to make improvements. Areas that are categorized as S3 has limiting factors, namely the danger level of erosion, nutrient retention, available nutrients, and rooting media. The dominant limiting factors are nutrient retention and available nutrients. This shows that the physiography and soil fertility are still a severe barrier to the use of this land. Improvements are needed to improve the land suitability class, such as providing adequate fertilizer for nutrient availability, and erosion control in accordance with conservation principles such as terrace construction.

In addition to seeing the quality of land suitability for rice plants, it is also necessary to know the nutritional value contained therein. The nutritional value of white rice can be presented in the following figure.

Nutritional Content of White Rice		
Energy (kkal)	:	360
Protein (g)	:	6.8
Fat (g)	:	0.7
Carbohydrate (g)	:	78.9
Calcium (mg)	:	6
Phosfor (mg)	:	140
Vitamin B1 (mg)	:	0.12

Figure 9. Rice and Nutritional Content of White Rice
(Source: Directorate of Nutrition, Ministry of Health, Republic of Indonesia)

3.2.2 Land Suitability of Corn

Corn plants require a rather rapid drainage with adequate aeration so that the roots of the plants can absorb nutrients well. Corn plants usually have clayey texture, dusty loam or sandy loam. The soil with fine texture has a stable aggregate stability because there are many adhesives that can strengthen the aggregate in clay.

Corn plants are able to develop and grow in areas with the altitude of 0-800 MASL and 800-1200 MASL (Meters Above Sea Level). The area at an altitude of more than 1200 meters above sea level is not good when planted with corn due to the wind conditions. A small number of research locations with the suitability of S1 can still be planted with corn in good condition.

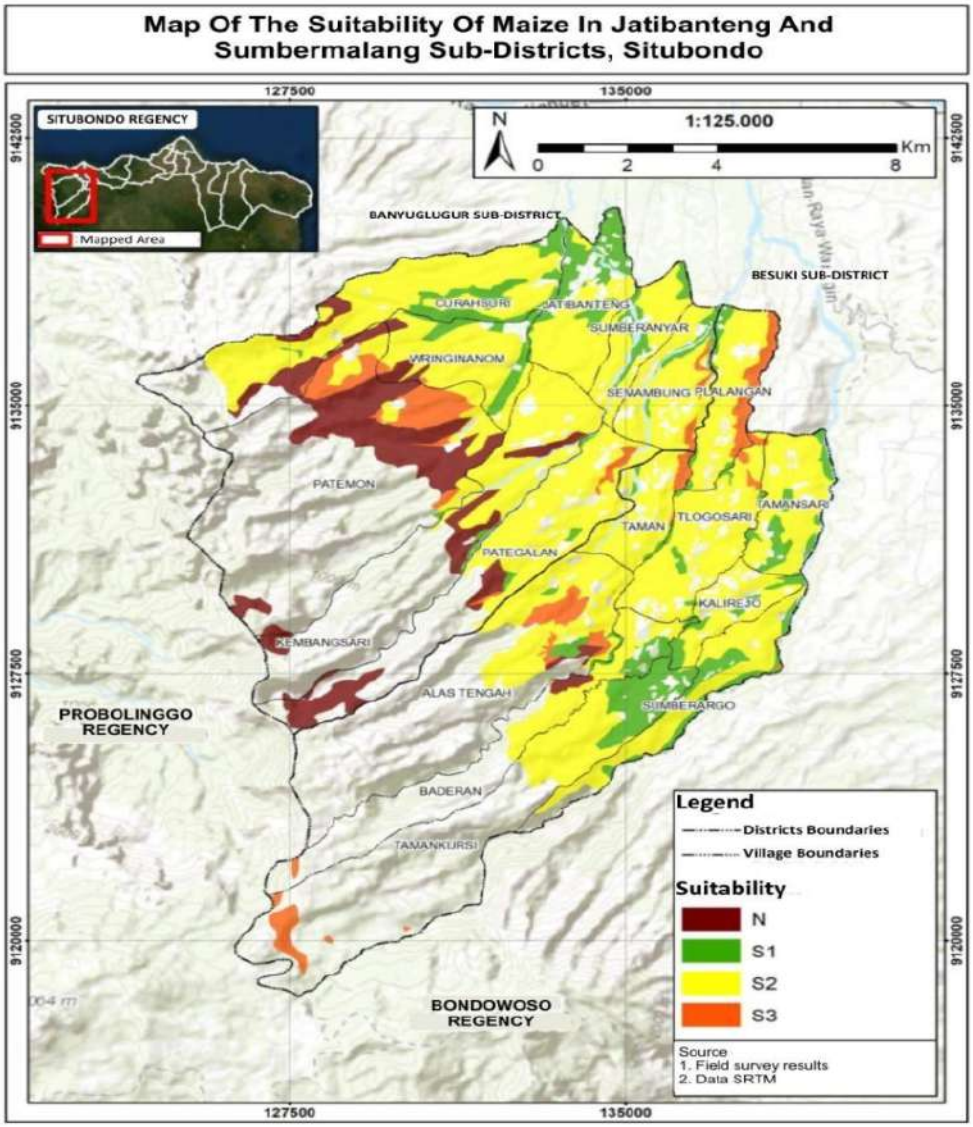

Figure 10. Suitability Land of Corn Plants in The Researched Area

From Figure 10, it can be explained that the researched areas of Jatibanteng and Sumbermalang Subdistrict are included in the S2 category which is dominantly suitable for the corn plantations (reach almost 85% of the land area). Only a small portion of the researched area that is included in the S1 category, so that not many people grow corns in Jatibanteng and Sumbermalang Subdistrict.

Table 4. Indicator Land Suitability of Corn Plants

Indicator	Category Land Suitability				Source
	S1	S2	S3	N	
CEC	>16	≤16			Djaenudin dkk, 2011 [4]
BS	>50	35-50	<35		Sareh & Rayes, 2019 [18]
C-Organic	>0.4	<0.4			Sareh & Rayes, 2019 [18]
Potassium	>20	2-20	<2		Sareh & Rayes, 2019 [18]
Slope	<8%	8-16%	16-30	>30	Djaenudin dkk, 2011 [4]
Phosphor	>40	20-40	<20		Sareh & Rayes, 2019 [18]

Information : Category S1 Highly Suitable, Category S2 Moderately Suitable, Category S3 Marginal Suitable, Category N Currently Not Suitable

Corn plants can grow optimally if the content of C-Organic in the soil > 0.4. So that all regions are included in the S2 class "quite suitable". For the corn plants, the limiting factors of land suitability are the danger level of erosion, nutrient retention, available nutrients, root media, and temperature. The dominant limiting factor is nutrient availability. This shows that the physiography, temperature, and soil fertility become a severe barrier for the use of this land. Controlling and overcoming the danger of erosion such as the establishment of terraces in accordance with the rules of soil conservation need to be done. Limiting soil fertility can be overcome by providing an adequate amount of fertilizer. In addition to seeing the quality of land suitability for rice plants, it is also necessary to know the nutritional value contained therein. The nutritional value of white rice can be presented in the following figure.

Corn has a nutritional value that is almost equivalent to the nutritional content in rice. As a substitute for rice for consumption, corn has an advantage over other food commodities, namely its sweet taste. The nutritional value of corn can be presented in the following figure.

Nutritional Content of Corn		
Energy (kkal)	:	307
Protein (g)	:	7.9
Fat (g)	:	3.4
Carbohydrate (g)	:	63.6
Calcium (mg)	:	9
Phosfor (mg)	:	148
Vitamin B1 (mg)	:	0.33

Figure 11. Corn and Nutritional Content of Shelled Corn
(Source: Directorate of Nutrition, Ministry of Health, Republic of Indonesia)

3.2.3 Land Suitability of Cassava

Cassava plants have relatively easy growing conditions. It can grow in the field under any conditions. The researched area has good regional characteristics for cassava plants because of the quality of the land. After knowing the suitability of the researched area based on its characteristics, it can be determined what suitable classes for cassava plants are in the researched area whether S1, S2, S3, or N. Based on the results of matching and scoring, the land suitability class for cassava plants in researched area was found.

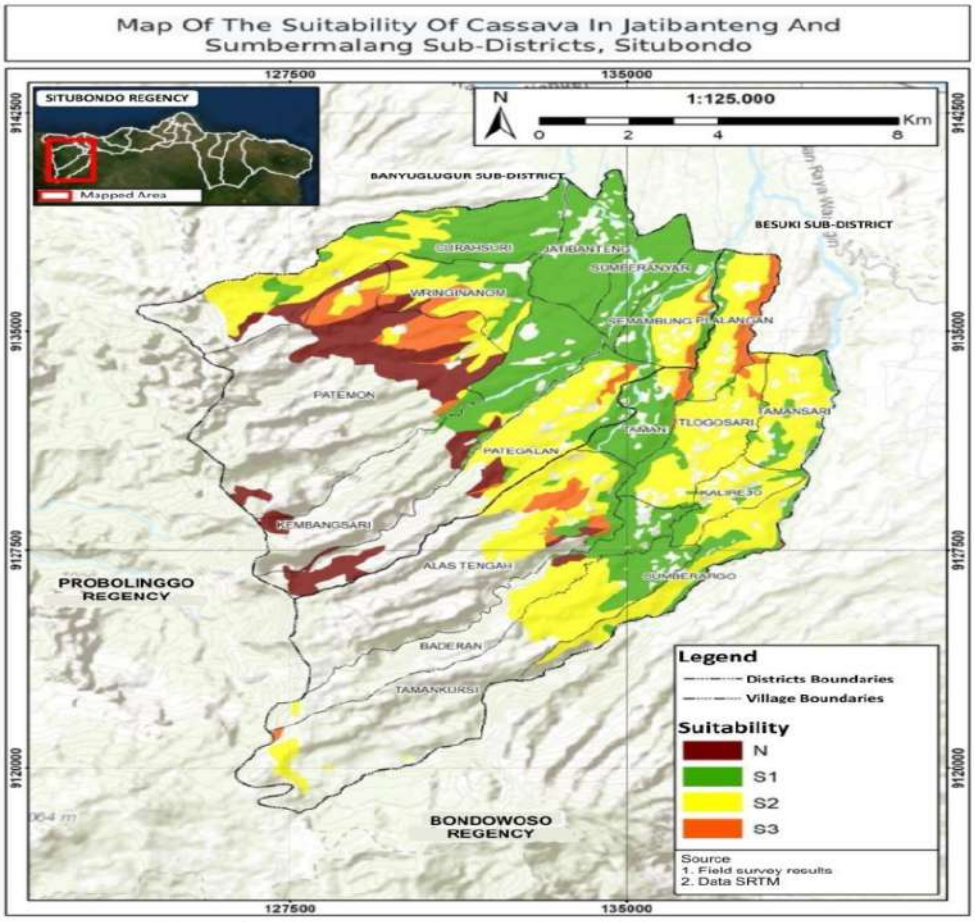

Figure 12. Suitability Land of Cassava Plants in The Researched Area

Most of the main areas in the north are very suitable for planting cassava. The area of land that has a very suitable (S1) category is dominated by Jatibanteng Subdistrict that reaches almost 50% of its area. It is reinforced with the findings in the field that many people have been growing cassava plants. Meanwhile in Sumbermalang Subdistrict, the suitability is dominated by suitability of good enough (S2) and some of those with the suitability of very suitable (S1).

Table 5. Indicator Land Suitability of Cassava Plants

Indicator	Category Land Suitability				Source
	S1	S2	S3	N	
CEC	>16	5-16	<5		Djaenudin dkk, 2011 [4]
BS	>50	35-50	<35		Sareh & Rayes, 2019 [18]
C-Organic	>0.4	<0.4			Sareh & Rayes, 2019 [18]
Potassium	>20	<20			Sareh & Rayes, 2019 [18]
Slope	<8%	8-16%	16-30	>30	Djaenudin dkk, 2011 [4]
Phosphor	>20	<20			Sareh & Rayes, 2019 [18]

Information : Category S1 Highly Suitable, Category S2 Moderately Suitable, Category S3 Marginal Suitable, Category N Currently Not Suitable

There is not much of a difference for the corn plants land suitability. Cassava plants can grow optimally if the content of C-Organic in the soil > 0.4. So that all regions are included in the S1 - S2 classes. The main limiting factors in the researched area are the rooting media and land preparation, namely effective soil depth and rock outcrop. Cassava plants need an effective soil of more than 100 cm, but from direct observations in the field, the effective soil depth did not reach 100 cm. For cassava plants, the land suitability limiting factors are the danger level of erosion, nutrient retention, available nutrients, root media, temperature, and water availability. The dominant limiting factors are nutrient retention, available nutrients, and rooting media. This shows that almost all of the land use criteria become the limiting factors. Administration of mulch on the land surface is useful to reduce evapotranspiration, while the use of appropriate irrigation is useful to cope with water availability. Fertilizers and ameliorant materials can increase nutrients and improve the soil's structure, as well as control and resolve the erosion with conservation technology.

Cassava is a food substitute for rice which has an important role for public consumption needs. Cassava has a very good nutritional value that is needed in maintaining a healthy body, because is a source of carbohydrate food. The nutritional value of cassava can be presented in the following figure.

Nutritional Content of Cassava		
Energy (kkal)	:	146
Protein (g)	:	1.2
Fat (g)	:	3.4
Carbohydrate (g)	:	63.6
Calcium (mg)	:	9
Phosfor (mg)	:	148
Vitamin B1 (mg)	:	0.33

Figure 13. Cassava and Nutritional Content of Cassava
(Source: Directorate of Nutrition, Ministry of Health, Republic of Indonesia)

4. Conclusion

The limiting factor that causes the fertility status to be low is the C-Organic. The low C-Organic is caused by the land management such as the lack in returning the leftover of the harvest to the soil. In general, the limiting factor that causes the status to be moderate in the researched area was due to the low value of BS (Base Saturation). The low in BS was assumed to be caused by the relatively high Na content. High Na content is not only damaging the soil structure, but also making the pH of the soil to be alkaline so that the cations become not optimal. The intensive addition of organic material into the soil must always be done so that the soil fertility status remains at high status. For example, returning the crop residues/leftover to the land, as well as the addition of compost from livestock manure are some of the appropriate ways in replacing the lost nutrients.

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