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Evaluation of Land suitability for sugarcane (*Saccharum officinarum* L.) for sustainable land use district Jagebob Merauke Regency

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Abstract. One of the areas prioritized for sugarcane expansion is Merauke district which is determined by Presidential Decree of the Republic of Indonesia Number 15 of 2024 concerning the Task Force for the Acceleration of Sugar Self-Sufficiency and Bioethanol in Merauke Regency, South Papua Province. Determination of Sugarcane Development Areas in Jagebob District, Merauke Regency is based on the analysis and evaluation of land suitability for sugarcane. Land suitability analysis uses GIS applications by conducting overlay and matching analysis on land suitability parameters such as rainfall, soil type, slope, soil texture and temperature. Data analysis uses matching and descriptive methods to determine the results of land evaluation assessments. The results of the land suitability class research in Jagebob District, Merauke Regency are marginal suitable (S3(oa,na)) with limiting factors including drainage (oa) and nutrient availability (na). After improving the limiting factors, the potential land suitability class can move up one level to a suitable land suitability class (S2(oa,na)). Improvement of limiting factors can be done by plowing the soil, applying organic materials and adding doses of P and K fertilizers.

1. Introduction

The Indonesian government is currently working to expand sugarcane planting areas outside Java through the National Sugar Self-Sufficiency Acceleration Program and Providing Bioethanol as biofuel. Efforts to expand the area require appropriate planning so that land use for sugar cane plantations can be utilized optimally and sustainably. A very important aspect in expanding the area is the capability/suitability aspect and the sustainability aspect of land resources. For this reason, it is necessary to have a comprehensive land suitability evaluation system. In fact, until now the land evaluation system specifically designated for sugar cane has not been widely developed. Sustainable land use is land use that can meet current needs, and at the same time can conserve land resources for future generations. In many cases of land damage to the point of giving rise to critical land, the main factor is land use that exceeds its carrying capacity and ignoring soil and water conservation principles in its management (1,2).

Merauke Regency, South Papua Province, based on the regulation of the Coordinating Minister for Economic Affairs (Permenko) Number 8 of 2023, dated 14 November 2023, concerning the Fourth Amendment to Permenko Number 7 of 2021 concerning Changes to the PSN List, Merauke Regency is included in the Merauke Food and Energy Development Area in South Papua Province. Furthermore, to accelerate regional development, the Government issued



Presidential Decree Number 15 of 2024 dated 19 April 2024 concerning the Task Force for Accelerating Sugar and Bioethanol Self-Sufficiency in Merauke Regency, South Papua Province. The Task Force was formed in order to accelerate the implementation of integrated investment activities in sugar cane plantations with the sugar, bioethanol and biomass power generation industries.

The sugar cane plant (*Saccharum officinarum*) belongs to the grass family which from the base to the stem contains sugar levels of up to 20%. Sugarcane plants can live from the lowlands to the highlands up to 1400 m above sea level. Suitable soil for sugar cane plants is soil that guarantees optimal water availability, soil acidity between 5.5 – 7.0 and sufficient nutrient availability to support its growth. For this reason, it is necessary to carry out land suitability evaluation assessments to obtain optimal results.

Evaluation of land suitability is needed in selecting land in order to expand land for planting a crop commodity (3). The level of suitability of land for planting or use for planting a commodity is seen from the level of land suitability. Evaluation of land suitability is necessary so that production can be maximized because the final result is location-specific land management based on the level of land suitability. The type of land use influences the land suitability class of an area. The level of land suitability is divided into two orders, namely S (Suitable) and N (Not Suitable) and this is useful as a basis for processing and utilizing land (4). This research aims to determine the characteristics and suitability classes of sugarcane land in Jagebob District, Merauke Regency so that the potential capacity of the land for sugarcane cultivation can be determined and efforts to improve it so that sugarcane yields can be optimal.

2. Method

This research was conducted in Jagebob District, Merauke Regency, South Papua Province from January 2022 to March 2023. The data collection method in the field was carried out using survey techniques to obtain primary data which includes spatial data (land physics), namely data on slope, drainage, effective depth, soil, soil texture, surface rocks, rock outcrops, erosion hazards and flood hazards) at the research location and continued with laboratory tests. The data analysis method used is the matching and descriptive method to determine the results of the land evaluation assessment Djaenudin et al. (4).

Evaluation of land suitability in this study uses qualitative methods, namely using the minimum law. In this method, matching is carried out between land quality and land characteristics as parameters with land suitability class criteria which have been prepared based on the use requirements or growing requirements of the plant or commodity being evaluated. The land suitability class conclusion is obtained from the land characteristics that have the lowest evaluation results (minimum value). Sugarcane crop commodities evaluated in the framework of sustainable agriculture in Merauke Regency. Requirements for growing sugar cane plants using modified Land Evaluation Technical Guidelines from Sarwono Hardjowigeno and Widiatmaka, 2011 and Wahyunto et al, 2016, Center for Research and Development of Agricultural Land Resources, Agricultural Research and Development Agency, Bogor shown in Table 1.

Table 1. Characteristics Land Suitability Class

Quality/ land characteristics		Land Suitability Class				
	Symbol	S1	S2	S3	N1	N2
Temperature	(t)					
1. Annual arochimahge (°C)		24-30	>30-32 22-<24	>32-34 21-<22	Td	>34 >21
Water availability	(w)					
1. dry month (<75mm)		3-4	2-<3	>4-5	-	>5 <2
2. rainfall/year (mm)		1500- 2500	1300- <1500	>2500-3000 1000-<1300	-	>3000 <1000
Rooting medium	(r)					
1. Soil drainage		Good	Medium	A bit slow, a bit fast	Slow, fast	Very slow, very fast
2. Texture		SL, L, SCL, SiL, Si, CL, SiCL	LS, SC, SiC, C	Str, C	-	Gravel, sand
3. Effective depth (cm)		>75	55-75	40-<55	30-<40	<30
Nutrient retention	(f)					
1. Soil Cation exchange capacity		≥ High	Medium	Low	Td	-
2. Base saturation (%)		>50	35-50	<35	-	-
3. Soil pH		5.5-<7.5	5.0-<5.5 7.5-8.0	<5.0 >8.0	-	-
Nutrients Availability	(n)					
1. Total N		≥Medium	Low	Very low	-	-
2. P ₂ O ₅		≥High	Medium	Very low	-	-
3. K ₂ O		≥High	Medium	Very low	-	-
Land Preparation	(p)					
1. Surface Rock (%)		<3	3-15	>15-40	Td	>40
2. Rock Outcrops (%)		<2	2-10	>10-25	>25-40	>40
3. Consistency, Grain Size		-	-	Very hard, very firm, very sticky	-	Gravel, rocky
Erosion Hazard Level	(e)					
1. Erosion Hazard		SR (very light)	R (light)	S (medium)	B (heavy)	SB (very heavy)
2. Slope (%)		<8	8-15	>15-30	>30	-
Flood Hazard	(b)	F0 (-)	F1 (light)	F2 (medium)	F3 (a bit heavy)	F4 (heavy)

3. Results and Discussion

3.1. General condition of the area

The Jagebob District research location is located between 1400.040'– 1400'.080' East Longitude and 70,060'– 80,000' South Latitude. Jagebob District has an area of 1,364.96 km², District. Jagebob has 14 villages, of which the largest village is Mimi Baru Village, 153.56 km² and the smallest village is Poo Village, which has an area of 21.16 km². Administratively, Jagebob District

is bordered by land. To the north it directly borders Sota District, to the east it borders Kurik District, to the south it borders Tanah Miring District and to the west it borders Animha District.

3.2. Climatic conditions

Based on the climate data obtained, the research location has an average rainfall of 1,558.56 mm/year with an average monthly rainfall of 129,880 mm/month and an average temperature of 28°C. Based on these data, it can be seen that based on the analysis of climate types in the study area using agro-climatic zones according to Oldeman (1975) where monthly rainfall is classified as Wet Month (WM) if the rainfall is greater than 200 mm/month and Dry Month (DM) if the rainfall is monthly is less than 100 mm/month, the rest are Humid Months (HM), so the climate type of the study area is included in agro-climatic zone C because it has 3 Wet Months (WM) and 3 Humid Months (HM) in a row. Based on this, in fact, according to the climate, sugar cane can grow well at the research location because it falls within the requirements for good sugar cane growth (5).

3.3. Slope

Based on the results of field observations at the research location in the Jagebob district, the plantation plans are at varying heights from 12.5 meters above sea level to 37.5 m above sea level or there is a height difference of 25 m. With a slope level of class A or included in the range of very flat slope class (slope between 0-3%) and flat slope class (slope 3 – 8%). The results of the analysis of research land characteristics in Jagebob District, Merauke Regency, South Papua Province, are shown in Table 2.

Table 2. Characteristics of research land.

Land Characteristics	Land Map Units		
	IK1	IK2	IK3
Temperature (tc)			
Annual Average temperature (°C)	28	28	28
Water availability (wa)			
Rainfall/year (mm)	129,880	129,880	129,880
Rainy day	11	11	11
Oxygen Availability (oa)			
Drainage	Hampered	Hampered	Hampered
Rooting media (rc)			
Texture	clay	clay	clay
Soil depth (cm)	40-55	40-55	40-55
Nutrient retention (nr)			
Soil Cation exchange (c mol/kg)	16.82	16,98	12.5
pH	6.8	6.75	6.75
C – organic (%)	2.22	1.7	2.22
Nutrients available (na)			
N(%)	0.29	0.54	1.06
P2O5(ppm)	0.72	0.32	0.34
K2O (mg/100g)	4.03	4.03	4.06
Erosion Hazard(eh)			
Slope (%)	13	10	11
eh	medium	light	light
Flood hazard(fh)			
Puddle	light	light	light
Land preparation (lp)			
Rocks on the surface (%)	10 – 15%	10 – 15%	10 – 15%
Rock outcrop (%)	10 – 15%	10 – 15%	10 – 15%

3.4. Soil texture

The soil texture at the research location in the Jagebob District is dominated by clay texture. Soil texture is closely related to the movement of water and dissolved substances, air, heat movement, soil volume weight, specific surface area, and compressibility. Qi et al., (6) stated that texture is also related to the level of soil plasticity, hardness, water binding capacity and permeability so that soil texture greatly affects soil fertility and ultimately affects plant growth and production.

3.5. Drainage conditions

Drainage conditions can be influenced by the type and texture of the soil, where the research location has a clay texture, with a soil layer with a depth of 40 cm. Judging from these conditions, it indicates that drainage at the location is hampered. Hampered drainage can cause less than optimal sugarcane growth such as stunted leaf growth, less than optimal stem diameter, low sugarcane shoots and low plant weight (7).

3.6. Effective soil depth

The effective soil depth in sugarcane fields at the research location ranges from 40 - 55 cm (Table 2), which is classified as a moderate category for sugarcane plant roots (8). However, in the land at the research location, the soil depth is <100 cm, of course there are factors that affect the growth of the roots not reaching their potential capacity. Generally, factors that can affect this are the presence of an inhibiting layer such as rock outcrops in the soil and solids or hard layers that inhibit root growth.

3.7. Soil Cation Exchange Capacity (CEC)

Cation Exchange Capacity (CEC) of soil indicates the maximum ability of soil to bind and exchange cations expressed in milliequivalents per 100 grams of absolute dry soil (me/100 g). The amount of CEC is influenced by the amount and type of clay minerals, texture and organic matter. CEC in the types of soil in the study area has a low to moderate value (5 - 241 me/100 g). This is because the clay content in these soils is quite dominant.

3.7.1. C-Organic

Organic matter is a supporting element for soil fertility, its influence on soil properties is improving soil structure, a source of nutrients C, N, P, S and micro elements, increasing the soil's ability to retain water, increasing the soil's ability to bind soil elements (increasing CEC) and a source of energy for microorganisms.

The results of the analysis of soil fertility conditions show that the levels of organic matter in the research area are in the very low - high category (0.47 This condition is caused by differences in the types of soil available. The mineral soil deposited in this area has a low organic matter content and some areas receive additional organic matter. The levels of organic C observed at the research location are low to moderate. Organic matter plays an important role in the physical condition of the soil, such as aeration, ease or difficulty of root penetration, ability to retain water or moisture, increase soil biological activity, maintain soil fertility and increase the availability of plant nutrients, increase nutrient absorption, pH remains a neutral state, and CEC Länder increases.

Organic matter is closely related to the amount of organic carbon (Corganik) content in the soil. Organic matter in the soil will undergo transformation where soil biota will continuously change organic components from one form to another. Hanafiah (2008), also explains that soil biota consumes organic matter which then produces by-products, waste and body tissue as a source of nutrients for plants (9). Carbon can be lost from the soil and plant tissue through the decomposition process to form CO₂, transported during harvests, used by soil biota and erosion (18).

3.7.2. pH of Soil

Plant growth depends on the pH value of the soil, which is determined by its hydrogen ion activity, so the pH level of an area is an important factor in determining plant nutrients. The soil pH of the research location was neutral with a pH value of 5.6 to 6.32. Sugarcane plants are semi-tolerant to soil acidity, can grow in the pH range of 4.0-8.2, but are optimal at a soil pH of 5.5-7.0 (10).

3.7.3. Nitrogen

Nitrogen is a macronutrient that can be produced from the decomposition process of organic soil materials. Sources of N in the soil are obtained from plant residues, manure, inorganic fertilizers (artificial fertilizers), ammonium salts and precipitated nitrates, and N fixed from the atmosphere carried out by certain microorganisms. The study area has a total N value ranging from very low to low (0.04 - 0.45%). The formation of chlorophyll in leaves and other sugarcane plant organs such as leaves, stems, shoots and roots, as well as enzymes in sugarcane plants are greatly influenced by nitrogen nutrients.

3.7.4. P Availability

Phosphorus is the second most important nutrient needed by plants after nitrogen. The availability of P in mineral soil is influenced by the number of other elements such as Ca and Al that can bind phosphorus so that its availability is less. In general, the potential concentration of phosphorus (P) at the research location is very low (8.3.3 - 11.24 ppm). The P element fixed by base cations (Ca, Mg) is responsible for most of the fluctuations in nutrient content. The levels of available P (P2O5) are low at the research location. Low soil P levels can be caused by several things, such as soil type and organic matter content. Plants experience decreased resistance to pests and diseases due to low P nutrient content, which causes slow growth.

3.7.5. K Availability

The K (K₂O) levels at the research location were relatively low, ranging from 0.11-0.26 mg/100g. The transfer and transportation of photosynthesis results to plant parts is greatly influenced by enzyme activity where potassium is an important nutrient in plants for enzyme activation (11).

3.8. Erosion and flood hazard

Erosion is an event where soil material moves from a higher place such as an upper slope by natural media (such as water and wind) to a lower area. This erosion event has been widely studied to be able to cause changes in the ecosystem so that in the end it can cause a decrease in land productivity, a decrease in the soil's ability to support plant growth and environmental quality (12). The danger of erosion levels at the research location based on observation results is categorized as light, where the sugarcane plantation land at the research location has a slope that is relatively flat ranging from 0-8%. The condition of the slope is flat, slightly wavy and quite gentle. Based on the results of observations, the duration of inundation/flood hazard at the research location is categorized as light, because the sugarcane plantation land at the research location is land with flat topography.

3.9. Evaluation of land suitability for sugarcane plants in Jagebob District

Land suitability evaluation is carried out based on comparative assessment of data obtained in the field with land suitability criteria for sugarcane plants which can be seen in Table 3. Based on the results of the land suitability assessment for sugarcane plants in Jagebob District, it was found that the actual Land Suitability Class (LSC) for each land characteristic is different. The annual average temperature obtained an actual LSC value that is very suitable (S1), in accordance with the comparison of field temperature data to the sugarcane plant characteristic guide which ranges from 24-30°C for the actual LSC value that is very suitable (S1). Then, in the rainfall/year

data, the actual LSC value was obtained as very suitable (S1). Drainage obtained an actual LSC value that is marginally suitable (S3), in accordance with the soil drainage conditions at the agricultural location which have grayish and yellowish spots on the soil layer which are classified into the obstructed category.

Table 3. Land suitability assessment for sugarcane planting in Jagebob District.

Land Characteristics	Land Map Unit		
	A	B	C
Temperature (tc)	S1	S1	S1
Annual average temperature (C)	S1	S1	S1
Water Availability (wa)	S2	S2	S2
Rainfall/year (mm)	S2	S2	S2
Oxygen Availability (oa)	S3	S3	S3
Drainage	S3	S3	S3
Rooting media (rc)	S2	S2	S2
Texture	S1	S1	S1
Soil depth (cm)	S2	S2	S2
Nutrient retention (nr)	S2	S2	S2
CEC (c mol/kg)	S1	S1	S2
pH	S2	S2	S2
C – organic (%)	S1	S1	S1
Nutrient availability (na)	S3	S3	S3
N(%)	S1	S1	S1
P2O5(ppm)	S3	S3	S3
K2O (mg/100g)	S3	S3	S3
Erosion hazard (eh)	S2	S1	S1
Slope (%)	S2	S1	S1
Erosion hazard	S2	S1	S1
Flood hazard (fh)	S2	S2	S2
Puddle	S2	S2	S2
Land preparation (lp)	S1	S1	S1
Rocks on the surface (%)	S1	S1	S1
Rock outcrop (%)	S1	S1	S1
Land Suitability Class	S3oa,na	S3oa,na	3oa,na

In the root media data (rc) which includes the texture and effective depth of the soil, the LSC value was obtained as suitable (S2), where for the actual LSC value of the soil texture, the effective depth of the soil is suitable (S2). In the nutrient retention data (nr) which includes CEC, soil pH and C-organic content in the soil, the actual LSC value is obtained according to (S2), with the CEC value of the soil being classified as low (15.41 cmol/kg), while for the actual LSC value of soil pH and C-organic it is very suitable (S1). In the results of the C-organic content, although it is classified as moderate with an average of 2.01%, the results are above the minimum value of the actual LSC very suitable (S1) of >0.8%. In the nutrient available data (na) which includes total N, available P and available K, the actual LSC value according to marginal (S3) is obtained with the

heaviest limiting factor being the available nutrient content of P and K in the soil which is classified as low so that the actual LSC value according to marginal (S3), while for the total N nutrient element, the LSC value is very suitable (S1) because the results of the total N content are above the minimum value of the actual LSC. Macronutrients for plants such as nitrogen (N), phosphorus (P), and potassium (K) are absolutely needed by plants in large quantities and if there is a deficiency of these nutrients, plant growth and yield will not be optimal (13). In the erosion hazard data (eh) covering the slope and erosion hazard level, the actual LSC value is obtained according to (S2), where the slope gradient and erosion hazard level are classified as moderate. High slopes and high slope lengths cause the level of damage due to erosion to increase because the speed of water flow is higher and the volume of water flowing on the surface is greater (14). In the old data on inundation/flood hazard, the actual LSC value is obtained according to (S2), where the flood hazard level is classified as mild. Based on the results above, it can be seen that the actual land suitability class for sugar cane plants in Jagebob District is classified as a marginal suitability class (S3oa,na) with limiting factors including:

3.9.1. Soil Drainage Conditions (oa)

Drainage conditions at the research location are categorized as obstructed, where in the soil layer with a depth of >15 cm there are grayish and yellowish spots indicating that the sand and iron content in the soil is quite high. Poor drainage conditions can cause low oxygen availability in the soil (15). Low oxygen availability in the soil can cause the aeration process in the soil to be disrupted which affects the obstruction of the soil drainage system. In addition, low oxygen availability in the soil can cause plant roots to be slow in absorbing nutrients and cause a reduction in nutrient levels in the soil so that plant growth is inhibited (16).

There are repair efforts that can be done to overcome the obstructed drainage conditions, where land processing can be done by plowing the soil and providing organic materials. Land processing is done to improve aeration in the soil, thereby facilitating the process of air exchange in the soil. Good aeration in the soil increases root development, soil fertility and soil porosity. The decrease in soil volume weight due to land processing can increase the number of micro pores in the soil because the weight of soil particles is getting smaller, so that the soil moisture storage capacity can increase. In addition, the decrease in soil volume weight can facilitate the soil drainage process because water is not blocked in the micro pores (1).

3.9.2. Low availability of soil nutrients P and K (na)

The availability of P and K nutrients at the research location is very low. The availability of P in the soil depends on several things, one of which is soil pH which influences the occurrence of fixation in the soil. The availability of K is the amount of K nutrients that can be exchanged and absorbed by plants with natural sources of K coming from the weathering of rocks containing potassium. This process dissolves minerals and will then be released into the soil system so that they are available for plants. There are several sources of K, namely orthoclase, biotite, muscovite and mica which are available for a long time. K from organic matter and in microbial populations is more readily available but has a small amount (2). There are efforts in improvement that can be made to overcome the low availability of P₂O₅ nutrients in the soil, namely by adding doses of P₂O₅ and K₂O nutrient fertilizers when carrying out fertilization activities. The provision of fertilizers containing P₂O₅ and K₂O nutrients is intended to increase the availability of K₂O nutrients in the soil in order to meet the needs of plants to grow and develop, there are several types of fertilizers containing P₂O₅ nutrients that can be used such as SP-18, SP-36 and TSP. Likewise, fertilizers containing K₂O nutrients are available in several types such as KCL 80 and KCL 90. There are several improvement efforts that can be made to overcome existing limiting factors. Through these improvement efforts, it is hoped that they will be able to reduce the negative impacts of existing limiting factors, and can increase the actual land suitability class from

marginally suitable (S3oa, na) to a potential land suitability class, namely suitable (S2oa, na) for sugarcane land in Jagebob District.

4. Conclusion

The actual land suitability class in Jagebob District for sugarcane planting land is marginally suitable (S3oa, na) with limiting factors in the form of drainage and available nutrients. Improvement efforts can be carried out by carrying out land processing such as plowing the land and providing organic materials and increasing the dose of P and K fertilizers. Improvement efforts made to drainage and available nutrients can increase the land suitability class from S3 to S2, so that the potential land suitability class becomes suitable (S2oa, na).

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