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Land Suitability Evaluation for Sugarcane (*Saccharum officinarum L.*) Cultivation in the Rejoso Watershed, Pasuruan Regency

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ABSTRACT

Land suitability evaluation is essential for optimizing crop productivity and promoting sustainable land use. In the Rejoso Watershed, Pasuruan Regency, sugarcane production remains suboptimal due to limited integration of biophysical land characteristics into cultivation management. This study aims to assess land characteristics, classify land suitability, identify limiting factors, and provide land management recommendations for sugarcane cultivation. The analysis considered key variables including temperature, rainfall, drainage, soil texture, effective depth, cation exchange capacity (CEC), base saturation, pH (H_2O), organic carbon, total nitrogen, available phosphorus (P_2O_5), available potassium (K_2O), slope, erosion risk, and flood risk. Land suitability was evaluated using a matching approach based on the *Buku Pedoman Penilaian Kesesuaian Lahan Komoditas Strategis* Year 2016. The results showed that actual land suitability comprises class S3 (Marginally Suitable), covering 22.262 ha (64.3%), and class N (Not Suitable), covering 12.342 ha (35.7%). Potential land suitability includes class S2 (Moderately Suitable), covering 8.562 ha (24.7%); class S3, covering 13.701 ha (39.6%); and class N, covering 12.342 ha (35.7%). The main limiting factors identified were temperature, drainage, soil texture, effective depth, nitrogen, phosphorus, base saturation, slope, erosion risk, and flood risk. Recommended management strategies include improving drainage using the Reynoso system, applying dolomitic lime, and SP36 fertilizer. Overall, the Rejoso Watershed demonstrates substantial potential for sugarcane development through improved land management. contributing to national sugar self-sufficiency.

Keywords: Cultivation, land suitability evaluation, matching method, Rejoso watershed, sugarcane

INTRODUCTION

Indonesia has a steadily increasing demand for sugar, but domestic production has not met national needs. Based on 2023 data, sugar consumption in Indonesia reached 6,9 million tons, while total national sugar production in the same year was recorded at 2,23 million tons (BPS, 2023a, 2023b). Therefore, the gap is filled through imports. The amount of sugar imported from 2019 to 2023 was 4 tons, 5,5 tons, 5,4 tons, 6 tons, and 5 tons, respectively. respectively (Supriyanti, 2024). As a strategic measure, the Indonesian government issued Presidential Regulation No. 40 of 2023 to accelerate national sugar self-sufficiency (Marpaung et al., 2025). Sugarcane productivity is increased through expanded planting areas, improved cultivation practices, and sustainable land-use planning (Dumipto et al., 2019).

Pasuruan Regency has great potential for sugarcane development due to its supportive agroecological conditions and the presence of P3GI (Indonesian Sugar Plantation Research Center) and the Kedawung Sugar Factory as supporting infrastructure. However, the average sugarcane productivity in Pasuruan for the 2019–2023 period was only around 5.97, 5.80, 6.27, 5.95, and 6.03 tons per hectare, respectively (BPS, 2024). This figure is much lower than the potential yield of a well-managed sugarcane cultivation system, which is up to 90 t ha^{-1} (Bantacut, 2013). This difference indicates inefficient land use and suggests that current cultivation practices are not fully aligned with the land's biophysical characteristics.

The Rejoso watershed is the largest river basin in Pasuruan Regency and plays an important role in supporting the community's livelihoods. Previous studies have shown that land conversion. erosion, and flooding are recurring problems in this watershed, which can threaten agricultural productivity and environmental sustainability (Amaruzaman et al., 2018; Putri & Priyadarshini, 2023). Therefore, any efforts to develop sugarcane in this region must be based on land suitability assessments to prevent further degradation.

Land suitability evaluation provides an important framework for adjusting land use to the specific needs of crops. According to the FAO (1976), land evaluation is the analysis of the suitability of land resource characteristics, such as climate, soil, and topography, to the ecological requirements of specific crops. Evaluations can be conducted under actual or potential conditions after management improvements. This approach is widely applied in agricultural planning to optimize productivity, minimize the risk of land degradation, and ensure sustainable use of resources (Ritung et al., 2011; Wahyunto et al., 2016).

Although land suitability assessments have been widely applied in Indonesia for various commodities, comprehensive research specifically evaluating sugarcane suitability in the Rejoso watershed remains limited. Most previous studies have focused on hydrological aspects, land use change, or conservation practices, but have not systematically assessed the capacity of this watershed to support large-scale sugarcane cultivation (Amalia et al., 2023; Firdaus et al., 2022). This information gap is problematic, given that Pasuruan Regency is a potential area for sugarcane development in East Java. Based on these issues, this study was conducted with three objectives: (i) to determine the characteristics of the land in the Rejoso watershed, (ii) to classify the actual and potential suitability of the land for sugarcane cultivation, and (iii) to identify limiting factors and provide land management recommendations.

MATERIALS AND METHODS

Time and Location of the Study

This research was conducted in the Rejoso watershed, Pasuruan Regency, East Java Province, from January to June 2025. The Rejoso watershed covers an area of 40,141 hectares and is geographically located at 7°372 193 –7°552 113 south latitude and 112°512 453 –113°032 253 east longitude. The altitude of the Rejoso watershed ranges from 0 to 2.763 meters above sea level. The research location is shown in Figure 1.

Research Method

This study used an exploratory descriptive method. Field surveys and soil sampling were conducted on 22 Land Map Units (LMU) in the Rejoso watershed (Table 1). Disturbed soil samples were collected at a 0-20 cm depth using a purposive random sampling method. Soil samples were analyzed at the Soil Fertility and Soil Health Laboratory and the Pedoclimatology and Land Resources Laboratory, Department of Soil Science,

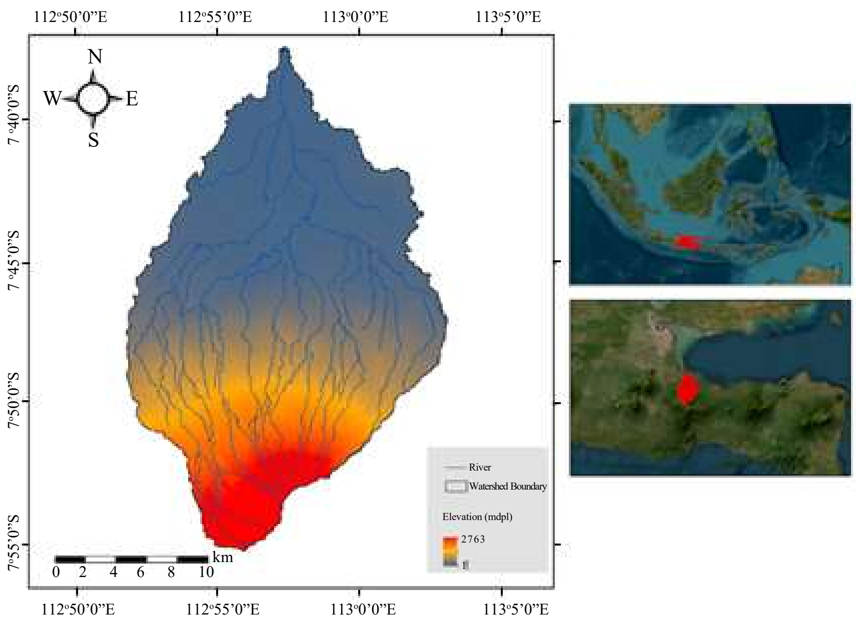

Figure 1. Map of the study area.

Table 1. Characteristics of land map units (LMU) in the Rejoso watershed.

SPL	Soil Type	Slope (%)	Land Use	Area		Sampling Coordinates	
				(ha)	(%)	X	Y
1	Vertisol	0-3	Upland	1,144	3.20	112° 58' 2" E	7° 44' 40" LS
2	Vertisol	0-3	Mixed Gardens	858	2.40	112° 58' 6" E	7° 43' 45" S
3	Inceptisol	3-8	Upland	5,504	15.38	112° 54' 20" E	7° 46' 43" S
4	Inceptisol	8-15	Upland	1,641	4.59	113° 0' 38" E	7° 49' 42" LS
5	Inceptisol	15-25	Upland	348	0.97	113° 0' 49" E	7° 49' 29" S
6	Andisol	8-15	Bushes	310	0.87	113° 0' 38" E	7° 49' 42" LS
7	Andisol	15-25	Bushes	1,249	3.49	112° 58' 17" E	7° 46' 8" S
8	Andisol	25-45	Bushes	1,976	5.52	112° 55' 20" E	7° 42' 29" S
9	Inceptisol	3-8	Plantation	1,307	3.65	112° 55' 12" E	7° 46' 38" LS
10	Inceptisol	8-15	Plantation	983	2.75	112° 56' 26" E	7° 49' 1" LS
11	Inceptisol	15-25	Plantation	214	0.60	112° 55' 18" E	7° 54' 18" S
12	Inceptisol	3-8	Bushes	604	1.69	112° 55' 28" E	7° 54' 31" LS
13	Inceptisol	8-15	Bushes	219	0.61	112° 52' 54" E	7° 49' 43" S
14	Vertisol	0-3	Rice Fields	7,418	20.73	113° 2' 18" E	7° 47' 26" S
15	Inceptisol	0-3	Rice Fields	1,287	3.60	113° 2' 19" E	7° 47' 20" LS
16	Andisol	8-15	Upland	3,201	8.95	113° 2' 29" E	7° 47' 11" S
17	Andisol	25-45	Upland	1,596	4.46	112° 58' 54" E	7° 46' 57" S
18	Andisol	15-25	Upland	1,992	5.57	112° 58' 5" E	7° 48' 4" S
19	Andisol	3-8	Mixed Gardens	191	0.53	112° 58' 18" E	7° 46' 8" S
20	Andisol	15-25	Mixed Gardens	779	2.18	112° 59' 56" E	7° 51' 11" LS
21	Andisol	8-15	Mixed Gardens	956	2.67	112° 59' 44" E	7° 51' 19" S
22	Vertisol	0-3	Plantation	672	1.88	112° 59' 6" E	7° 51' 45" S
Total Area				34,604	100		

Table 2. The parameters and analysis methods.

Land Characteristics	Method	Reference
Soil Texture Class	Hydrometer	(Bouyoucos, 1927)
Soil pH	Measurement using pH meter 1:5	(Eviati & Sulaiman, 2009)
N-Total	Kjeldahl	(Kjeldahl, 1883)
Available P	Olsen	(Olsen et al., 1954)
Available K	NH_4OAc Extract 1M pH 7	(Chapman, 1965)
Cation Exchange Capacity (CEC)	NH_4OAc Extract 1M pH 7	(Chapman, 1965)
Ca, Na, Mg	NH_4OAc Extract 1M pH 7	(Chapman, 1965)
C-Organic	Walkley & Black	(Walkley & Black, 1934)
Salinitas (DHL)	Measurement using EC Meter	(Eviati & Sulaiman, 2009)
Temperature (°C)	Citra Satelit (MODIS)	https://lpdaac.usgs.gov/products/mod11a2v061/
Rainfall (2014-2023) (mm/tahun)	Satellite Imagery (CHIRPS)	https://www.chc.ucsb.edu/data/chirps
Slope (%)	Spatial Analysis	(Moore et al., 1991)
Erosion Hazard (ton/ha/year)	RUSLE	(Renard et al., 1997)
Soil Depth (cm)	Field Observation	(Sukarman et al., 2017)
Drainage	Field Observation	(Sukarman et al., 2017)
Flood Hazard	Interview	(Sukarman et al., 2017)

Table 3. Criteria for land suitability classes of sugarcane.

Terms of Use/ Land Characteristics	Land Suitability Class			
	S1	S2	S3	N
Temperature (tc)				
Temperature (°C)	24 - 28	>28 – 31 22 -< 24	>31–33 21 -< 22	>33 <21
Water availability (wa)				
Annual rainfall (mm/year)	1,500-2,500	1,300-<1,500	1,000-<1,300 >2,500-3,000	<1,000 >3,000
Oxygen availability (oa)				
Drainage	well, quite good	Slightly hampered	Stuck, slightly fast	Highly inhibited, fast
Rooting media (rc)				
Soil texture	rather fine, medium	Smooth	Slightly rough	Rough
Soil depth (cm)	> 100	75-100	50 - 75	<50
Retention of Sins (nr)				
Soil CEC (cmol)	>16	5-16	<5	
Base saturation (%)	>50	35-50	<35	
pH H_2O	5.5 – 7.5	5.0 – 5.5 7,5 - 8,0	<5,0 >8,0	
Organic-C (%)	>1.2	<0.8-1.2	<0,8	
Nutrient availability (na)				
N-total (%)	Medium	Low	Very low	
P_2O_5 (ppm)	>75	25-75	<25	
K_2O (ppm)	>150	75-150	<75	
Toxicity (xc)				
Salinity (dS/m)	< 5	5-8	8-10	>10
Erosion hazards (eh)				
Slope (%)	<3	3-8	8-15	>15
Erosion hazards		Very light	Mild-medium	Heavy-very heavy
Flood hazards (fh)				
-Height (cm)	-	-	25	>25
-Duration (hari)	-	-	<7	>7

Sumber: (Djaja et al.. 2024; Kementerian Pertanian. 2015; Wahyunto et al.. 2016)

Faculty of Agriculture, University of Jember. The parameters and analysis methods are presented in Table 2.

Land suitability assessment is carried out by matching land characteristics with land-use requirements, crop growth, management, and conservation requirements (Ritung et al., 2011). The determination of sugarcane land suitability refers to the book "Petunjuk teknis pedoman penilaian kesesuaian lahan untuk komoditas pertanian strategis tingkat semi detail skala 1:50.000 oleh Balai Besar Sumberdaya Lahan Pertanian Tahun 2016". All spatial data were processed using ArcGIS 10.8 software for spatial analysis and map creation. The land characteristics of each LMU are matched with the growth requirements of sugarcane (*Saccharum officinarum* L.) presented in Table 3. The matching results yield actual and potential land suitability classes. The suitability classes consist of: highly suitable (S1). moderately suitable (S2), marginally suitable (S3), and unsuitable (N).

RESULTS AND DISCUSSION

Land characteristics

Land characteristics were assessed based on actual conditions and used to analyze the suitability of the land for sugarcane cultivation in the Rejoso watershed. Land characteristics were

Table 4. Land characteristics of the Rejoso watershed.

LMU	Soil Texture Class	pH H_2O	Total N (%)	Available P (ppm)	Available K (ppm)	CEC (cmol/kg)	BS (%)	C-Organic (%)	EC	Temp.	Rainfall (mm/year)	Slope (%)	Erosion hazard	Effective Soil depth (cm)	Drainage	Flood hazard
1	Medium	7.34	0.17	8.1	235	28.64	30.63	1.86	0.149	26	1838	0-3	Very Low	Deep	Good	-
2	Medium	7.06	0.2	6	685	37.07	24.49	3.3	0.093	26	1819	0-3	Very Low	Moderate	Poor	Duration <7 days Height > 25 cm
3	Smooth	6.84	0.16	4.2	166	29.18	23.77	1.25	0.087	26	1974	3-8	Low	Moderate	Good	
4	Moderately Coarse	6.44	0.24	5.3	232	26.45	29.22	2.19	0.131	25	2081	3-8	Low	Deep	Good	-
5	Moderately Smooth	6.46	0.11	5.2	286	29.23	25.78	1.61	0.091	25	2095	15-25	Low	Moderate	Moderate	-
6	Moderately Coarse	6.38	0.2	3.2	129	24.57	25.44	1.98	0.11	22	2281	8-15	Very Low	Deep	Good	-
7	Moderately Coarse	6.33	0.24	3.8	163	31.97	22.83	1.39	0.095	21	2401	15-25	Low	Deep	Moderate	-
8	Moderately Coarse	6.3	0.17	1.5	117	22.05	29.55	1.6	0.088	20	2418	15-25	Low	Deep	Moderate	-
9	Moderately Coarse	6.16	0.13	25.6	333	30.6	27.12	1.43	0.172	26	1995	3-8	Very Low	Shallow	Good	-
10	Moderately Coarse	6.24	0.06	5.8	381	32.26	25.53	1.71	0.129	25	2065	8-15	Heavy	Shallow	Good	-
11	Moderately Smooth	6.14	0.11	12.8	184	38.41	19.52	1.59	0.189	25	2067	15-25	Heavy	Shallow	Moderate	-
12	Smooth	6.1	0.24	2.5	243	30.55	25.69	1.14	0.184	27	1988	3-8	Low	Deep	Good	-
13	Medium	6.5	0.08	4	229	33.6	24.45	1.06	0.266	26	2053	8-15	Heavy	Shallow	Good	-
14	Moderately Smooth	7.44	0.29	19.3	216	40.98	35.13	1.43	0.127	26	1808	0-3	Very Low	Moderate	Poor	-

obtained from field observations, laboratory analysis, and secondary data processing. The land characteristics of the Rejoso watershed are presented in Table 4.

The temperature in the Rejoso watershed ranges from 19°C to 27°C. The minimum temperature required to support water and nutrient absorption is 19°C to 20°C, while the maximum is 28°C to 30°C (Pramuhadi, 2010). The average annual rainfall in the Rejoso River Basin is recorded at 2,117 mm yr^{-1}. This value is generally close to the optimal requirements for sugarcane, which requires rainfall of around 200 mm per month during the 5–6-month growth phase. 125 mm per month during the 2-month transition period, and less than 75 mm per month during the 4–5-month ripening phase (Hartatie et al., 2021).

The effective soil depth in several LMUs is 25–50 cm with an area of 4,011 ha, a depth of >50–<100 cm with an area of 20,992 ha, and a depth of 100–<150 cm with an area of 9,601 ha. Soil depth can be a limiting factor for root media, as sugarcane plants require sufficient root space to support stem growth that can reach heights of up to 4 meters (Basuki et al., 2022). Drainage conditions in the Rejoso watershed are generally good, covering 16,066 ha. A comparison of good and poor drainage conditions in the Rejoso watershed is shown in Figure 2. Sugarcane requires 10% aeration for root respiration and cannot tolerate prolonged flooding (Hunsigi, 2001). Impaired drainage can reduce the number of sugarcane tillers, green leaves, stem nodes, stem diameter, and stem height, thereby reducing plant weight and increasing the number of adventitious roots (Permana et al., 2018). Adventitious roots reduce stem sucrose levels to adapt to soil oxygen deficiency (Basuki et al., 2022).

The slope gradient in the Rejoso watershed ranges from 0% to 45%. Land with a slope gradient >20% can still be used for sugarcane cultivation but requires intensive soil conservation measures (Mulyono, 2011). The risk of erosion ranges from very low to very high, with surface soil loss reaching 12.51 cm yr^{-1}. Based on the Erosion Hazard Level (EHL) classification, the Rejoso watershed has four criteria: very light covering 92.66 km^2, light covering 58.06 km^2, moderate covering 179.17 km^2, and heavy covering 30.41 km^2 (Amalia et al., 2023). Flooding is one of the obstacles to sugarcane cultivation in the Rejoso watershed, especially in LMU 2 and 22, where waterlogging has been recorded with an average depth of >25 cm. Sugarcane plants can survive in flooded conditions for a short time, but this can increase the risk of fungal, viral, and bacterial diseases (Sys et al., 1993). Based on the level of flood vulnerability, the Rejoso watershed and surrounding areas are classified into four classes, namely highly vulnerable (7,172 ha), vulnerable (2,071 ha), moderately vulnerable (860 ha), and not prone (30 ha), spread across the subdistricts of Lekok, Nguling, Grati, Rejoso, Bugul Kidul, Gondang Wetan, and Winongan (Jusfarida and Syafirina, 2021). Therefore, areas with a high risk of flooding are not suitable for sugarcane cultivation without drainage improvements or other management measures.

The Rejoso watershed has soil textures ranging from slightly coarse to medium, slightly Smooth, and

Figure 2. Soil drainage conditions in the study area: (a) Well-drained at LMU 1 and (b) poorly drained at LMU 22.

Smooth. Sugarcane plants grow optimally in soils with a slightly Smooth to medium texture (Wahyunto et al., 2016). Clay soils are considered more ideal for agriculture because they retain moisture and provide plants with a more consistent water supply (Widjajanto et al., 2024). Base saturation (BS) in the Rejoso watershed is classified as low to very low. Low BS reflects the dominance of acid cations such as Hz and Al^{3}z , which contribute to soil acidity and reduce nutrient availability. This condition is generally correlated with low soil pH. Sugarcane plants can grow at pH 4.5–8.5, but optimal growth occurs at 5.5–7.5 (Hunsigi, 2001).

The cation exchange capacity (CEC) of soil in the Rejoso watershed is classified as moderate to very high. The highest value was recorded in LMU 14 (40.98 cmol kg^{-1}) with vertisol soil type. Vertisol soil contains a 2:1 clay mineral that can absorb and retain large amounts of cations (Kadarwati, 2016). The organic C content at LMU 2, 4, and 15 is >2%, reflecting a high level of organic matter. Land use in these LMUs includes mixed gardens, dry fields, and rice fields. According to Bakri et al. (2016), the highest organic C value was found in forest land (3.07%), followed by mixed gardens (2.57%), shrubs (2.01%), and dry fields (1.03%).

Macro nutrients such as nitrogen (N), phosphorus (P), and potassium (K) are important components in supporting sugarcane growth. Nitrogen content in the Rejoso watershed is classified as low to moderate. Nitrogen requirements for sugarcane reach around 160 kg ha^{-1} (Basuki et al., 2022). In the Rejoso watershed, the lowest phosphorus content was recorded at 1.5 ppm in LMU 8 with andisol soil type. Andisol soil has high phosphate retention (>85%) (Fiantis, 2016). The exchangeable K content in the Rejoso watershed ranges from 54 ppm to 685 ppm. Potassium availability is influenced by soil parent material and acidity (pH) (Winazira and Sufardi, 2021).

The soil salinity level in the Rejoso watershed is classified as low to moderate. The salinity tolerance threshold for sugarcane is 1,7 dS m^{-1} (Morais et al., 2022). Sugarcane plants are more

Table 5. Actual land suitability classes and limiting factors for sugarcane.

LMU	Actual Land Suitability	Area	
		Ha	%
1	S3 (nr2, na2)	1,144	3.3
2	N (fh1)	858	2.5
3	S3 (oa1, rc2, nr2, na2, eh2)	5,504	15.9
4	S3 (rc1, nr2, eh2, na2)	1,641	4.7
5	N (eh1,eh2)	348	1.0
6	S3 (rc1, nr2, na2, eh1)	310	0.9
7	N (eh1)	1,304	3.8
8	N (tc1, eh1)	2,028	5.9
9	N (rc2)	1,307	3.8
10	N (rc2)	983	2.8
11	N (rc2, eh1, eh2)	214	0.6
12	S3 (nr2, na2, lp1)	604	1.7
13	N (rc2)	218	0.6
14	S3 (oa1, na2)	7,417	21.4
15	S3 (oa1, rc2, nr2, na2)	1,287	3.7
16	S3 (rc2, nr2, na2, na3, eh1, eh2)	3,207	9.3
17	N (tc1, eh1, eh2)	1,605	4.6
18	N (eh2)	2,027	5.9
19	S3 (rc1, nr2, na2)	191	0.6
20	N (eh1)	784	2.3
21	S3 (rc1, nr2, na2, na3, eh1, eh2)	956	2.8
22	N (fh1)	666	1.9
	Total	34,604	100

Note: temperature (tc); drainage (oa); soil texture (rc1); effective depth (rc2); base saturation (nr2); available phosphorus (na2); potassium (na3); flood hazard (fh); slope (eh1); and Erosion Hazard Level (eh2) sensitive to salinity stress in the seedling phase. The photosynthesis process will be inhibited by salt accumulation in the mesophyll tissue, which increases CO_2 concentration in the intercellular space, thereby reducing stomatal opening (da Silva et al., 2008). Clones that are resistant to salinity stress are PS-864, PS-862, Bululawang, VMC, and HWY Merah (Sari et al., 2019).

Actual Land Suitability

Actual suitability is determined based on current natural conditions, without any improvements. Land suitability assessment is based on the prerequisites for sugarcane cultivation according to the 2016 Strategic Commodity Land Suitability Assessment Guidelines. The actual land suitability class and limiting factors for sugarcane cultivation in the Rejoso watershed are presented in Table 5.

Based on the actual land suitability evaluation, the Rejoso watershed has two suitability classes: S3 (Marginal Suitability) and N (Not suitable). The S3 class includes LMU 1, 3, 4, 6, 12, 14, 15, 16, 19, and 21 with an area of 22,262 ha (64,3%). The N (Not suitable) class includes LMU 2, 5, 7, 8, 9, 10, 11, 13, 17, 18, 20, and 22, covering 12,342 ha (35,7%). The distribution of actual land suitability for sugarcane cultivation in the Rejoso watershed is shown in Figure 3. Based on Figure 3, class S3 dominates the central and downstream areas of the Rejoso watershed. Rice fields and sugarcane plantations dominate the downstream area of the Rejoso watershed (Amaruzaman et al., 2018). Meanwhile, the N land suitability class dominates the upstream area of the Rejoso watershed. The factors limiting suitability in the upstream area are slope gradient and erosion hazards. This is because sugarcane has a fibrous root system, which is less effective at retaining soil particles to prevent erosion. The displacement of topsoil due to erosion reduces soil fertility (Romadhon and Hermiyanto, 2021). Lukito's (2019) research shows that the subdistricts with dominant sugarcane areas are Grati (27.29%), Nguling (15.89%), Winongan (15.41%), and Gondang Wetan (7.12%).

We can raise the actual land suitability rating of class S3 to class S2 by considering the limiting factors that can be improved. Limiting factors in actual land suitability include temperature (tc), drainage (oa), soil texture (rc1), effective depth (rc2), base saturation (nr2), available phosphorus (na2), potassium (na3), flood hazard (fh), slope (eh1), and Erosion Hazard Level (eh2), Temperature, soil texture, and effective depth are permanent limiting factors and therefore cannot be improved. The coarser the soil texture, the less water it can provide for plants (Cahyono et al., 2019). Meanwhile, soil fertility can be improved because nutrients are not permanent limiting factors. Nutrient availability is not a major limiting factor in assessing land suitability, as it can still be overcome through land management

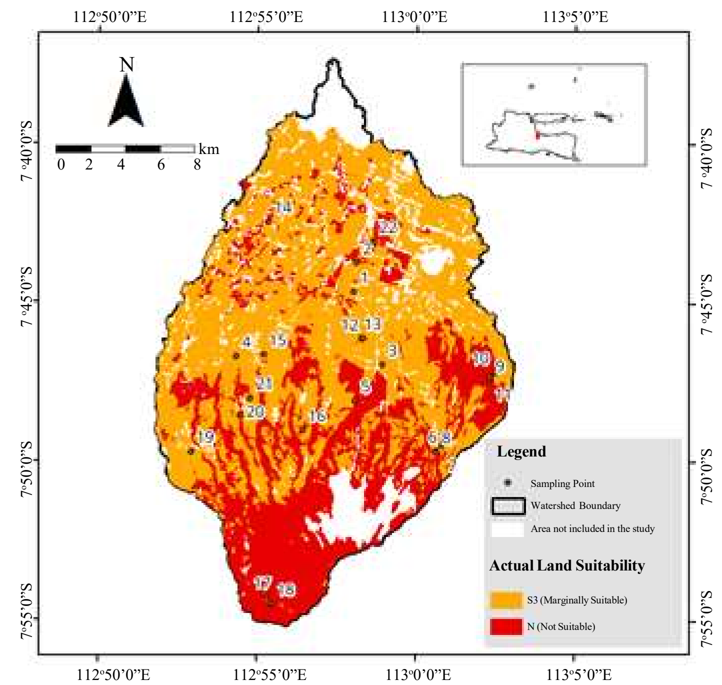

Figure 3. Actual land suitability map for sugarcane in the Rejoso Watershed.

Table 6. Potential land suitability classes and limiting factors for sugarcane.

LMU	Potential Land Suitability	Area	
		Ha	%
1	S2 (nr2. na2)	1,144	3.3
2	N (fh1)	858	2,5
3	S3 (rc2)	5,504	15.9
4	S3 (rc1)	1,641	4.7
5	N (eh1, eh2)	348	1.0
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12	S3 (lp1)	604	1.7
13	N (rc2)	218	0.6
14	S2 (oa1, na2)	7,417	21.4
15	S3 (rc2)	1,287	3.7
16	S3 (rc2, nr2, eh1, eh2)	3,207	9.3
17	N (tc1, eh 1,eh2)	1,605	4.6
18	N (eh2)	2,027	5.9
19	S3 (rc1)	191	0.6
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21	S3 (rc1, eh1, eh2)	956	2.8
22	N (fh1)	6,666	1.9
	Total	34,604	100

Note: temperature (tc); drainage (oa); soil texture (rc1); effective depth (rc2); base saturation (nr2); available phosphorus (na2); potassium (na3); flood hazard (fh); slope (eh1); and Erosion Hazard Level (eh2)

such as adding nutrients to the soil (Harahap et al., 2020). Nutrient retention is an indicator of soil quality that acts as a limiting factor at the conditional suitability (CS) level for sugarcane crops (Mulyono, 2009). According to the FAO (1976), unsuitable land has limiting factors that can be overcome, but requires an investment that is not proportional to the returns.

Potential Land Suitability

Potential land suitability is the level of land suitability obtained after considering specific inputs and management actions on each land unit (Hartati et al., 2018). The potential land suitability class for sugarcane cultivation in the Rejoso watershed is presented in Table 6.

Based on Table 6, there are three classes of potential land suitability: S2, S3, and N. Class S2 includes LMU 1 and 14, with an area of 8,562 ha (24,7%). Class S3 includes LMU 3, 4, 6, 12, 15, 16, 19, and 21 with an area of 13,700 ha (39,6%). Class N includes LMU 2, 5, 7, 8, 9, 10, 11, 13, 17, 18, 20, and 22 with an area of 12,342 ha (35,7%). This assessment is based on the potential to address the limiting factors in the actual conditions. However, not all limiting factors can be improved technically or economically. Therefore, any management intervention aimed at improving land quality from actual to potential conditions must consider environmental sustainability and feasibility through cost-benefit analysis (Basuki et al., 2022). The distribution of potential land suitability is shown in Figure 4. Based on the distribution of potential land suitability, class S2 dominates the downstream area of the Rejoso watershed, class S3 dominates the central area, and class N continues to dominate the upstream area because it has limiting factors that are difficult to improve. Erosion rate as a limiting factor arises from long-term monoculture cultivation practices that do not consider soil quality, thereby

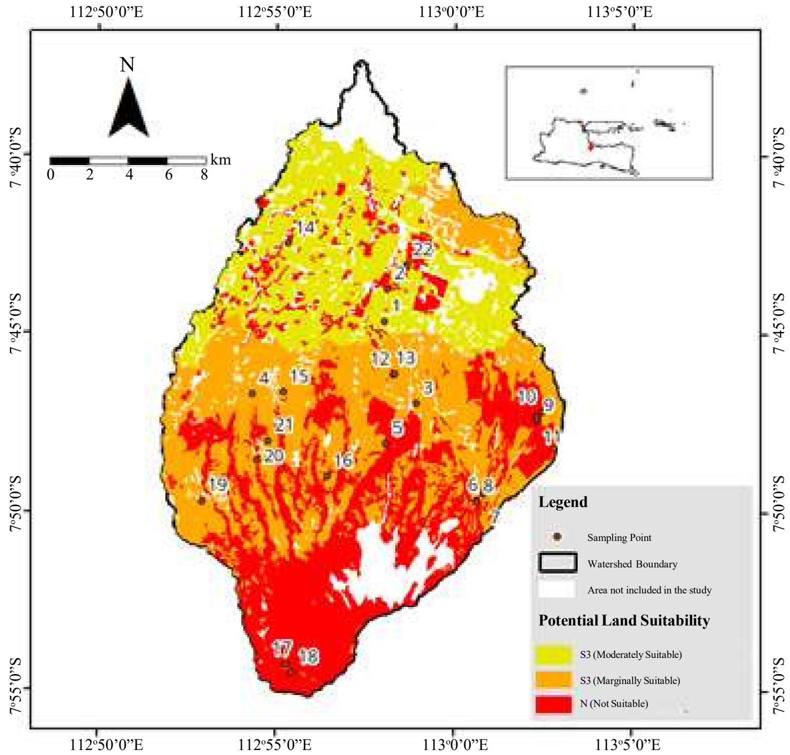

Figure 4. Potential land suitability map for sugarcane in the Rejoso Watershed.

providing the basis for the proposed integrated management model across the Arjasa sub-watershed area (Hermiyanto et al., 2025). Erosion rates can be reduced by constructing terraces, contour planting, or planting ground cover, but on slopes steeper than 30%, management is costly (Hartati et al., 2018).

Efforts to improve the suitability of actual land for potential land are constrained by several factors, namely drainage (oa), base saturation (nr2), and available phosphorus (na2). Land management in the Rejoso watershed requires a strategy based on specific interventions, including drainage improvement using the Reynoso method. The Reynoso system is a manual soil cultivation system for rice fields that involves creating water channels that serve as water inlets and outlets (Kementerian Pertanian, 2015). The perimeter ditch has a width of 70 cm at the top, 50 cm at the bottom, and a depth of 100 cm. The mujur ditch has a width of 60 cm at the top, 40 cm at the bottom, and a depth of 80 cm. The malang ditch has the same dimensions, with a width of 50 cm at the top, 30 cm at the bottom, and a depth of 70 cm (Kementerian Pertanian, 2015). Improvement of base saturation with dolomite lime application. An increase in pH increases base saturation because Ca^{2+} and Mg^{2+} ions replace H^+ and Al^{3+} ions in the soil cation exchange complex. Dolomite ($CaMg(CO_3)_2$) increases base saturation, soil pH, and the availability of Ca and Mg for plant growth (Sihombing et al., 2019). Dolomite contains calcium (Ca) and magnesium (Mg) (Basuki and Sari, 2019). Phosphorus availability improves with the application of SP36 fertilizer. Mulyono's (2009) research shows that soil with very low phosphorus content requires 215 kg ha^{-1} of SP-36 fertilizer, applied once during soil cultivation. Fertilization of sugarcane plants is carried out in two stages, namely two weeks after planting with the application of 1/3 of the urea dose, the entire SP-36 dose, and 1/3 of the KCl dose, followed by six weeks after planting with the remaining urea and KCl doses (Kiswanto and Wijayanto, 2014). Organic matter increases soil phosphorus availability through mineralization, which releases phosphate ions (PO_4^{3-}) (Syahidah and Hermiyanto, 2019). Phosphorus application has a positive effect on sugarcane stalk growth (El-Tilib et al, 2004).

CONCLUSIONS

The evaluation results show that most of the Rejoso watershed area has the potential to support sugarcane cultivation, especially after interventions to manage limiting factors. The results showed that actual land suitability comprises class S3 (Marginally Suitable), covering 22,262 ha (64,3%), and class N (Not Suitable), covering 12,342 ha (35,7%). Potential land suitability includes class S2 (Moderately Suitable), covering 8,562 ha (24,7%); class S3, covering 13,701 ha (39,6%); and class N, covering 12,342 ha (35,7%). The increase in suitability class from S3 to S2 on some of the land shows that technical improvements such as liming, drainage improvements, and phosphorus fertilization can significantly increase land carrying capacity. However, land with an N (Not suitable) class that has not undergone any changes indicates permanent limitations and requires an assessment of alternative land uses. The strategic recommendation is to implement integrated land management that considers technical, economic, and ecological aspects to support sustainable sugarcane productivity in the Rejoso watershed.

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