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Potential of Former Sand Mining Land for Durian Cultivation: Case Study in Ngrogung Village, Ponorogo, East Java

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ABSTRACT

Ngrogung is one of the sand mining areas in Ponorogo, East Java, Indonesia. Post-mining, this area often remains underutilized. One potential application for this former sand mining land could be the cultivation of durian plants. The research aims to determine land characteristics and evaluate the level of land suitability for Durian cultivation. The research was conducted using survey methods. Determining the research location was carried out purposively based on conditions in the field. The study area is 20 hectares, which is an ex-sand mining area. Determination of representative samples was carried out in a zigzag manner to obtain a representative sample. Soil samples were taken to a depth of 100 cm, representing the root area of the durian plant. Sample analysis was carried out using the method issued by the Land Resources Center, and the results obtained were analyzed using matching methods based on FAO criteria. The results showed that the actual land suitability of the ex-sand mining in Ngrogung Village is S3nr-2 covering an area of 10 hectares with alkaline saturation limiting factor, S3nr-4; eh-2 with C-organic and erosion hazard limiting factor 6 hectares, S3nr-4; rc-2 with C organic and crude material limiting factor 4 hectares. The potential suitability of ex-sand mining land based on FAO criteria can be categorized as S2 (quite suitable), so it requires technological input such as adding organic matter, making terraces, and planting according to contours.

Keywords: *Durio zibethinus*; FAO Criteria; Land Characteristics; Land suitability; Sand mining

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INTRODUCTION

Land use through mining activities has predominantly resulted in significant environmental degradation, including alterations in land function and the loss of fertile topsoil, particularly in the context of sand mining (Abdurachman et al. 2008; Eviati and Sulaeman 2009). The exploration, extraction, production, and subsequent sale of natural resources can result in land being designated as critical after it has been abandoned (Djajadi et al. 2011). This critical land, generated from sand mining, is typically categorized as unproductive and remains underutilized (Gavrilescu 2021). Restoring soil fertility on such land can be effectively achieved by applying soil amendment materials, which can enhance the physical and chemical properties of the soil (Morash et al. 2024). Importantly, ex-sand mining land possesses substantial potential for agricultural expansion, provided it undergoes reclamation efforts to improve its carrying capacity and usability for biomass production (Hamdani et al. 2020; Fauzan et al. 2022). Land extensification can be realized by transforming marginal land and open fields into productive areas for cultivation. This approach supports sustainable agricultural practices, as outlined in Republic of Indonesia Law No. 41, 2009, on sustainable protection of food agricultural land, Chapter 4 Article 29.

Ponorogo, located in East Java province, is characterized by areas designated for sand mining, particularly in Ngrogung Village, which is situated within the Ngebel District. Covering an area of 503 hectares and located at an elevation of approximately 385 meters above sea level, Ngrogung Village is endowed with abundant natural resources, primarily sand. The extensive sand deposits within this village have established it as a notable sand mining site in Ponorogo Regency, with mining operations spanning approximately 28 hectares and a permit allowing activities to continue until 2045. Consequently, mining operations have left behind around 20 hectares of ex-sand mining land, which remains unused mainly for agricultural purposes or other activities.

Ngrogung Village is recognized as a durian cultivation center in Ponorogo, designated by the government to support local durian varieties, precisely the Kanjeng variety of *Durio zybethinus* Murray. Expanding the

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agricultural area is necessary to develop this region further as a durian center. The ex-sand mining land in Ngrogung Village presents a viable opportunity for such expansion. This region receives an annual rainfall of 2000 to 3000 mm, with temperatures ranging from 18 to 31°C. It includes various soil types such as the Yellowish-Brown Andosol Association, Dark Brown Litosol, Mediterranean Association, and Brown Litosol (BPS-Statistics Ponorogo Regency 2024).

The approximately 20-hectare ex-sand mining area in Ngrogung Village, Ngebel District, Ponorogo Regency, offers significant potential for the expansion or extensification of agricultural land. This considerable land area could be designated for the cultivation of durian, with the expectation that such extensification will enhance productivity and elevate the durian harvest in Ngrogung Village, recognized as the center for durian farming in Ponorogo Regency. Therefore, it is crucial to evaluate the land conditions of the former sand mining area to determine their suitability for durian cultivation in Ngrogung Village. The primary objective of this research is to assess the land characteristics and evaluate the suitability level for durian cultivation.

MATERIALS AND METHODS

The research was conducted in Ngrogung Village, located in Ngebel, Ponorogo, East Java, an area characterized by soils associated with yellowish-brown Latosol and brown Litosol, with temperatures ranging from 18 to 31°C. The hilly terrain of Ngrogung Village is rich in natural resources, particularly sand, which has led to active sand mining operations covering 28 hectares of land. These operations are permitted to continue until 2045 (BPS-Statistics Ponorogo Regency 2024). However, the impact of sand mining has resulted in a low topographic slope in the ex-mining area.

Representative samples were identified by creating triangular polygons, which segmented the areas into a zigzag pattern according to the prevailing land conditions (Figure 1). Soil samples were collected to a depth of 100 cm, representing the root zone of the durian plant. The laboratory analyses of these soil samples adhered to the Technical Instructions for Soil Analysis as outlined by Eviati and Sulaeman (2009). Data interpretation followed land evaluation procedures, which involved comparing land criteria for plant growth against the results of the completed analyses. Land suitability classes were determined using a weighting factor method, which aligns data on primary limiting factors with established criteria. The classification of land suitability includes categories S1 (very suitable), S2 (suitable), S3 (marginally suitable), and N (not suitable), as defined by the FAO (1981) and Hardjowigeno and Widiatmaka (2007). Additionally, Table 1 outlines the requirements and conditions for land suitability for durian cultivation.

Figure 1. Research location and determination of representative samples

Table 1. Land Suitability for Durian Plants (Hardjowigeno and Widiatmaka 2007)

Land use requirements/ characteristic	Class of land suitability			
	S1	S2	S3	N
Temperature (tc)				
Average temperature (°C)	22 – 28	28 – 34	34 – 40	> 40
		18 – 22	15 – 18	< 15
Water availability (wa)				
Rainfall (mm)	1000 – 2000	500 – 1000	250 – 500	< 250
		2000 – 3000	3000 – 4000	> 4000
Oxygen availability (oa)				
Drainage	Good, medium	A bit hampered	Hampered, rather fast	Very hampered, fast
Root media (rc)				
Texture	Fine, slightly fine, medium	-	Slightly coarse	Coarse
Rough material (%)	< 15	15 – 25	35 – 55	> 55
Soil depth (cm)	> 100	75 – 100	50 – 75	< 50
Nutrient retention (nr)				
CEC (cmol(+)/kg)	> 16	≤16		
Base saturation (%)	> 35	20 – 35	< 20	
pH H_20	5.0 – 6.0	4.5 – 5.0	< 4.5	
Organic C (%)	> 1.2	6.0 – 7.5	> 7.5	
		0.8 – 1.2	< 0.8	
Nutrient available (na)				
Total N (%)	Medium	Low	Very low	
P_2O_5 (cmol(+)/kg)	Medium	Low	Very low	
K_2O (cmol(+)/kg)	Medium	Low	Very low	
Erosion hazard (eh)				
Slope (%)	< 8	8 – 16	16 – 30	> 30
Erosion hazard	Very low	Low - medium	heavy	Very heavy
Flood hazard (fh)				
Puddle of water	F0	F1	F2	> F2
Land preparation (lp)				
Surface rocks (%)	< 5	5 – 15	15 – 40	> 40
Rock outcrops (%)	< 5	5 – 15	15 – 25	> 25

The research used a survey method that included observational data collection and the gathering of both primary and secondary data. According to Kabir (2016), the survey method is a research technique that involves direct observation of a phenomenon or the collection of information through interviews. The selection of observation locations was determined by analyzing the area's topography using Google Earth software. Primary data was collected from 20 representative samples, focusing on soil analysis and land conditions based on parameters for assessing land suitability for durian (Abdurachman et al. 2008; Eviati and Sulaeman 2009; Aini et al. 2021). Secondary data encompassed climatic factors such as temperature, humidity, and rainfall, as sourced from the statistical records of the Ponorogo district (BPS-Statistics Ponorogo Regency 2024).

RESULTS AND DISCUSSIONS

Ngrogung Village has varied topography, including both flat and hilly areas. The hilly regions contain significant sand deposits, which have been exploited for sand mining activities. This has led to the creation of ex-sand regions that remain largely underutilized. Table 2 presents an analysis of the environmental and soil samples. The results show that most representative samples are suitable for cultivating durian plants; however, some limiting factors were identified at specific sampling points.

Table 2. The actual class of land suitability for durian plants on ex-sand mining land in Ngrogung Village

Land characteristics	Representative samples													
	PNG 1		PNG 2		PNG 3		PNG 4		PNG 5		PNG 6		PNG 7	
	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class
Temperature (tc)														
Average temperature (oC)	23.91	S2	23.91	S2	23.91	S2	23.91	S2	23.91	S2	23.91	S2	23.91	S2
Water availability (wa)														
Rainfall (mm)	2,849	S1	2,849	S1	2,849	S1	2,849	S1	2,849	S1	2,849	S1	2,849	S1
Humidity (%)	68.3	S1	68.3	S1	68.3	S1	68.3	S1	68.3	S1	68.3	S1	68.3	S1
Oxygen availability (oa)														
Drainage	medium	S1	medium	S1	medium	S1	medium	S1	medium	S1	medium	S1	medium	S1
Root media (rc)														
Texture	Fine	S1	Slightly fine	S1	Slightly fine	S1	Fine	S1	Fine	S1	Slightly fine	S1	Slightly fine	S1
Coarse material (%)	50	S3	40	S3	30	S2	30	S2	30	S2	30	S2	30	S2
Soil depth (cm)	>100	S1	>100	S1	>100	S1	>100	S1	>100	S1	>100	S1	>100	S1
Nutrient retention (nr)														
CEC (cmol(+)/kg)	14.10	S2	12.10	S2	11.09	S2	8.07	S2	17.14	S1	11.09	S2	11.10	S2
Base saturation (%)	0.84	S3	0.94	S3	0.89	S3	0.88	S3	0.64	S3	0.89	S3	0.97	S3
pH H20	5.63	S1	5.69	S1	5.75	S1	5.78	S1	5.74	S1	5.75	S1	5.70	S1
Organic C (%)	0.26	S3	0.21	S3	0.15	S3	0.12	S3	0.08	S3	0.15	S3	0.04	S3
Nutrient available (na)														
Total N (%)	0.22		0.19		0.15		0.12		0.23		0.15		0.22	
	Medium	S1	Low	S2	Low	S2	Low	S2	Medium	S1	Low	S2	Medium	S1
P_2O_5 (cmol(+)/kg)	32.78		114.28		92.89		99.26		110.67		92.89		110.72	
	Medium	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1
K_2O (cmol(+)/kg)	104.48		94.53		8.40		87.40		94.11		83.42		84.75	
	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1
Erosion hazard (eh)														
Slope (%)	3	S1	4	S1	4	S1	2	S1	3	S1	5	S1	7	S1
Erosion hazard	Low	S1	Low	S1	Low	S1	Low	S1	Low	S1	Low	S1	Low	S1
Flood hazard (fh)														
Puddle of water	F0	S1	F0	S1	F0	S1	F0	S1	F0	S1	F0	S1	F0	S1
Land preparation (lp)														
Surface rocks (%)	2	S1	1	S1	0	S1	10	S2	0	S1	0	S1	0	S1
Rock outcrops (%)	0	S1	0	S1	0	S1	0	S1	0	S1	0	S1	3	S1
The Actual of land suitability class sub-class level	**S3-nr,rc**		**S3-nr.rc**		**S3-nr**		**S3-nr**		**S3-nr**		**S3-nr**		**S3-nr,eh**	
The Actual of land suitability class unit level	**S3nr-2,4;rc-2**		**S3nr-2,4;rc-2**		**S3nr-2,4**		**S3nr-2,4**		**S3nr-2,4**		**S3nr-2,4**		**S3nr-2,4;eh-2**	

Land characteristics	Representative samples													
	PNG 8		PNG 9		PNG 10		PNG 11		PNG 12		PNG 13		PNG 14	
	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class
Temperature (tc)														
Average temperature (oC)	23.91	S2	23.91	S2	23.91	S2	23.91	S2	23.91	S2	23.91	S2	23.91	S2
Water availability (wa)														
Rainfall (mm)	2,849	S1	2,849	S1	2,849	S1	2,849	S1	2,849	S1	2,849	S1	2,849	S1
Humidity (%)	68.3	S1	68.3	S1	68.3	S1	68.3	S1	68.3	S1	68.3	S1	68.3	S1
Oxygen availability (oa)														
Drainage	medium	S1	medium	S1	medium	S1	medium	S1	medium	S1	medium	S1	medium	S1
Root media (rc)														
Texture	Slightly fine	S1	Slightly fine	S1	Slightly fine	S1	Slightly fine	S1	Fine	S1	Fine	S1	Fine	S1
Coarse material (%)	30	S2	30	S2	40	S3	20	S2	20	S1	30	S2	30	S2
Soil depth (cm)	>100	S1	>100	S1	>100	S1	>100	S1	>100	S1	>100	S1	>100	S1
Nutrient retention (nr)														
CEC (cmol(+)/kg)	12.10	S2	13.10	S2	12.10	S2	11.10	S2	16.11	S1	8.07	S2	12.40	S2
Base saturation (%)	0.94	S3	0.89	S3	0.94	S3	0.97	S3	0.57	S3	0.88	S3	0.83	S3
pH H20	5.69	S1	5.75	S1	5.69	S1	5.70	S1	5.65	S1	5.78	S1	5.70	S1
Organic C (%)	0.21	S3	0.03	S3	0.21	S3	0.04	S3	0.24	S3	0.08	S3	0.13	S3
Nutrient available (na)														
Total N (%)	0.19		0.13		0.19		0.22		0.20		0.12		0.32	
	Low	S2	Low	S2	Low	S2	Low	S2	Low	S2	Low	S2	Medium	S1
P_2O_5 (cmol(+)/kg)	114.28		129.75		114.28		110.72		128.99		99.26		109.45	
	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1
K_2O (cmol(+)/kg)	94.53		88.31		94.53		84.5		96.02		87.40		86.65	
	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1
Erosion hazard (eh)														
Slope (%)	5	S1	3	S1	4	S1	4	S1	4	S1	4	S1	5	S1
Erosion hazard	Low	S1	Low	S1	Low	S1	Low	S1	Low	S1	Low	S1	Low	S1
Flood hazard (fh)														
Puddle of water	F0	S1	F0	S1	F0	S1	F0	S1	F0	S1	F0	S1	F0	S1
Land preparation (lp)														
Surface rocks (%)	0	S1	0	S1	0	S1	0	S1	0	S1	0	S1	0	S1
Rock outcrops (%)	0	S1	0	S1	0	S1	0	S1	0	S1	0	S1	0	S1
The Actual of land suitability class sub-class level	**S3-nr**		**S3-nr.rc**		**S3-nr,rc**		**S3-nr,eh**		**S3-nr**		**S3-nr, eh**		**S3-nr,eh**	
The Actual of land suitability class unit level	**S3nr-2,4**		**S3nr-2,4;rc-2**		**S3nr-2,4;rc-2**		**S3nr-2,4;eh-2**		**S3nr-2,4**		**S3nr-2,4,eh-2**		**S3nr-2,4;eh-2**	

Land characteristics	Representative samples											
	PNG 15		PNG 16		PNG 17		PNG 18		PNG 19		PNG 20	
	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class
Temperature (tc)												
Average temperature (oC)	23.91	S2	23.91	S2	23.91	S2	23.91	S2	23.91	S2	23.91	S2
Water availability (wa)												
Rainfall (mm)	2,849	S1	2,849	S1	2,849	S1	2,849	S1	2,849	S1	2,849	S1
Humidity (%)	68.3	S1	68.3	S1	68.3	S1	68.3	S1	68.3	S1	68.3	S1
Oxygen availability (oa)												
Drainage	medium	S1	medium	S1	medium	S1	medium	S1	medium	S1	medium	S1
Root media (rc)												
Texture	Slightly fine	S1	Slightly fine	S1	Fine	S1	Fine	S1	Fine	S1	Slightly fine	S1
	10		30								30	
Coarse material (%)	>100	S1	>100	S2	20	S2	40	S3	20	S1	>100	S2
Soil depth (cm)		S1		S1	>100	S1	>100	S1	>100	S1		S1
Nutrient retention (nr)												
CEC (cmol(+)/kg)	13.10	S2	13.10	S2	13.11	S2	14.10	S2	19.86	S1	12.40	S2
Base saturation (%)	0.89	S3	0.89	S3	0.87	S3	0.84	S3	0.56	S3	0.83	S3
pH H20	5.75	S1	5.75	S1	5.57	S1	5.63	S1	5.73	S1	5.70	S1
Organic C (%)	0.03	S3	0.03	S3	0.24	S3	0.26	S3	0.60	S3	0.13	S3
Nutrient available (na)												
Total N (%)	0.13		0.13		0.15		0.22		0.22		0.32	
	Low	S2	Low	S2	Low	S2	Medium	S1	Medium	S1	Medium	S1
P_2O_5 (cmol(+)/kg)	129.75		129.75		27.30		32.78		20.04		109.45	
	Very high	S1	Very high	S1	Very high	S1	Medium	S1	Low	S2	Very high	S1
K_2O (cmol(+)/kg)	88.31		88.31		95.94		104.48		122.80		86.65	
	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1	Very high	S1
Erosion hazard (eh)												
Slope (%)	5	S1	4	S1	4	S1	4	S1	4	S1	5	S1
Erosion hazard	Low	S1	Low	S1	Low	S1	Low	S1	Low	S1	Low	S1
Flood hazard (fh)												
Puddle of water	F0	S1	F0	S1	F0	S1	F0	S1	F0	S1	F0	S1
Land preparation (lp)												
Surface rocks (%)	0	S1	0	S1	0	S1	0	S1	0	S1	0	S1
Rock outcrops (%)	0	S1	3	S1	3	S1	1	S1	0	S1	0	S1
The Actual of land suitability class sub-class level	**S3-nr,eh**		**S3-nr.eh**		**S3-nr**		**S3-nr**		**S3-nr**		**S3-nr**	
The Actual of land suitability class unit level	**S3nr-2,4,eh-2**		**S3nr-2,4;eh-2**		**S3nr-2,4**		**S3nr-2,4;rc-2**		**S3nr-2,4**		**S3nr-2,4**	

Table 2 outlines the primary limiting factors affecting the cultivation of durian plants. The average annual temperature in Ngrogung Village is approximately 23.91°C. According to the land suitability criteria, the area is classified as S2 (suitable). Air temperature plays a crucial role in physiological processes, influencing stomatal opening activity, transpiration rates, water and nutrient absorption rates, photosynthesis, and respiration in plants. Temperature fluctuations significantly affect plant growth rates, particularly in the partitioning of photosynthate among various plant organs (Chauhan et al. 2023). Data from the Ponorogo Meteorology and Geophysics Agency indicates that water availability in this region is favorable for durian cultivation, with sufficient rainfall, humidity, and good drainage conditions for oxygen availability. Water is essential for plant growth, serving as a solvent and nutrient carrier from the rhizosphere to the roots and subsequently to the leaves. It is also vital for transporting and distributing nutrients throughout the plant (Gavrilescu 2021; Alaoui et al. 2022). Furthermore, oxygen is critical for metabolic processes, and its availability is closely linked to soil drainage (Tufaila et al. 2014).

Regarding the rooting medium parameters, both soil texture and depth are highly suitable for durian cultivation. Nonetheless, coarse materials in the area have resulted in a classification of S3 (marginal suitability). According to Woldeyohannis et al. (2024) and Syamsiyah et al. (2023), soil's chemical and physical properties are significantly influenced by its texture. A dominance of clay particles can hinder root penetration due to reduced soil porosity. Conversely, clay-rich soils tend to be more fertile, as clay particles serve as soil colloids—electrically charged particles that facilitate the exchange of anions and cations, thereby influencing nutrient levels and availability. Durian plants possess a stable taproot system; these roots develop fine root hairs that effectively absorb nutrients and water. However, fine root hairs thrive optimally in soils with a low percentage of coarse materials or in fine-textured soils. Excessive coarse material can restrict the growth of root hairs, limiting their access to water and nutrients. The S3 land suitability classification may negatively impact plant productivity, but improvements can be made by incorporating organic materials. Organic matter enhances the physical properties of soil, including soil structure, temperature regulation, aggregate stability, air retention capacity, and resilience against erosion, and it serves as an energy source for soil microorganisms (Usharani et al. 2019; Sun et al. 2023).

Regarding nutrient retention parameters, base saturation, and organic carbon content are deemed less suitable for durian cultivation, categorizing them in land suitability class S3 (marginally suitable). Nutrient retention is an essential soil fertility parameter that reflects the chemical properties influencing the movement, supply, and absorption of nutrients from the soil to plants, thereby affecting overall soil fertility. Base saturation represents the proportion of base cations to the total cation pool (including both base and acid cations) within the soil adsorption complex (Tufaila et al. 2014). Soils characterized by low base saturation typically exhibit low cation content as well.

The availability of nutrients in the ex-sand mining land of Ngrogung Village is relatively favorable. Nitrogen levels fall within land suitability classes S1 and S2, while phosphorous and potassium availability are classified in land suitability class S1. The adequate availability of nitrogen, phosphorous, and potassium (NPK) is critical, as these macronutrients are absorbed by plants predominantly in their ionic forms—cations and anions (Alaoui et al. 2022; Priya et al. 2024).

Plants require these nutrients as primary energy sources, with nitrogen playing a vital role in vegetative growth, affecting the development of leaves, stems, and roots. However, nitrogen is often the most limited nutrient in agricultural soils, as it is absorbed by plants in the largest quantities (Barłóg et al. 2022). Phosphorous is crucial for the formation of components in living cells and is particularly abundant in seeds and growing points. It plays a significant role in energy transfer, which is critical for growth and other biological processes. Similarly, potassium is essential, with plants absorbing it as K+. In plant tissues, potassium is primarily retained as K+ ions and is involved in various metabolic processes, including photosynthesis and respiration (Sardans and Peñuelas 2021).

Field observations indicate that the slope of the land in this area ranges from less than 3% to 15%, rendering it highly suitable for durian cultivation. Furthermore, the risk of flooding is negligible across all areas, as they are situated in hilly regions, thus classifying this land as S1 (very suitable). Although the ex-sand mining sites in Ngrogung Village are located on hills, sand mining activities have resulted in a reduced land slope. Importantly, there are no limiting constraints regarding land preparation parameters, affirming its classification as S1 for durian cultivation. The current land suitability map for durian plants is illustrated in Figure 2. The various limiting factors identified in Figure 2 can be mitigated, allowing this area to be effectively utilized for durian cultivation by addressing these constraints.

The primary limiting factors affecting ex-sand mining land in Ngrogung Village are nutrient retention, erosion hazards, and root conditions. Base saturation is a critical limiting factor for nutrient retention, as it is closely associated with soil pH and overall fertility. Soils exhibiting a base saturation between 50% and 80% indicate medium fertility, while those with a base saturation below 50% are considered infertile. The low concentrations of exchangeable calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), and sodium (Na^{+}) in the ex-sand mining soils, despite high cation exchange capacity (CEC), hinder the absorption of nutrients, particularly exchangeable bases, by plants. Increasing soil base saturation can typically be achieved through lime application; fertilizers containing primarily calcium carbonate ($CaCO_3$) and magnesium oxide (MgO) can serve as alkaline sources for the soil (Abou Hussien et al. 2020). Additionally, the availability of organic carbon can be enhanced by incorporating organic materials through the application of organic fertilizers.

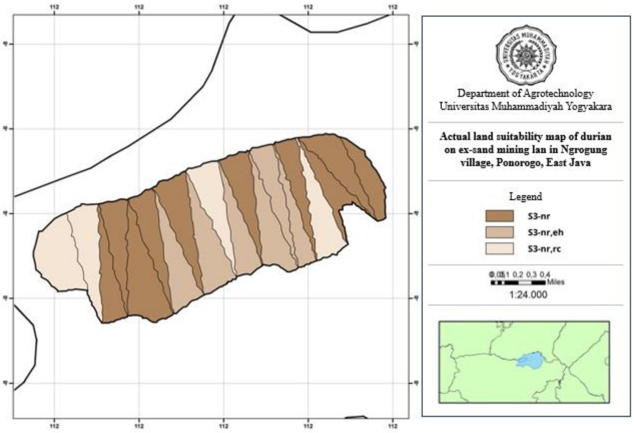

Figure 2. The actual land suitability class map for durian plants in Ngrogung Village

The second limiting factor is the risk of erosion. Mitigation strategies for erosion on ex-sand mining land may involve the establishment of contour strips and the replanting of ground cover species. Cover crops are also employed to further prevent erosion on exposed surfaces. Such plantings aim to reduce surface runoff velocity and promote water infiltration. Additionally, cover crops contribute to the restoration of soil physical properties by fixing nitrogen from the atmosphere. Desired characteristics for effective cover crops include ease of establishment, rapid and dense growth, a symbiotic relationship with beneficial microorganisms (such as Rhizobium, Frankia, Azospirillum, and mycorrhizal fungi), high biomass production with quick decomposition, non-competitiveness with primary crops, and non-twining growth habits (Abdurachman et al. 2008).

The final limiting factor pertains to root conditions. The presence of coarse materials in the soil significantly impedes the penetration of durian roots at certain locations. The abundance of coarse materials may result from the residual effects of sand mining activities. An increased proportion of coarse soil materials adversely affects the soil's physical properties, particularly its water retention capacity. As the percentage of coarse soil increases, the soil's ability to retain water diminishes. This is particularly evident in soils with a clay-sand texture, where an elevated rate of coarse materials leads to reduced water retention capabilities (Djajadi et al. 2011; Abdullahi et al. 2019). Enhancements to ex-sand mining land can be facilitated through the addition of organic matter, such as compost derived from agricultural residues.

Following these improvements, the potential land suitability classification for this area is anticipated to increase by one level. Most regions are projected to achieve a land suitability classification of S2 (suitable) for durian cultivation. A hypothetical map illustrating this potential land suitability is presented in Figure 3.

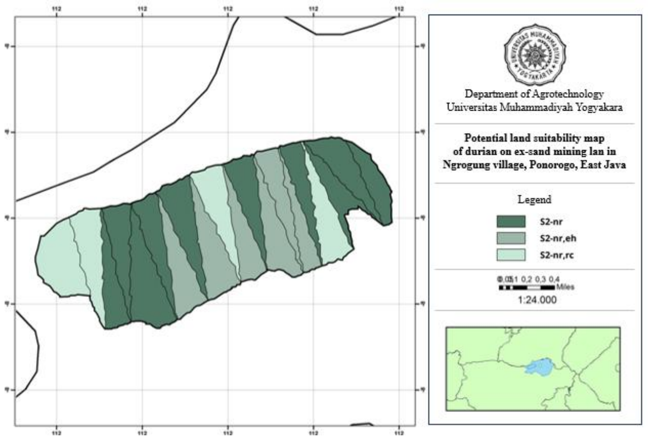

Figure 3. Map of potential land suitability classes for durian plants in Ngrogung Village

CONCLUSIONS AND SUGGESTIONS

The current land suitability classification of the ex-sand mining land in Ngrogung Village, Ngebel District, Ponorogo Regency, East Java Province is categorized as marginally suitable (S3), with limiting factors including base saturation, organic carbon content, the presence of coarse materials, and the risk of erosion. Following the implementation of improvement measures, the potential land suitability classification in this area has been elevated by one level, thereby classifying it as suitable (S2) for durian cultivation. However, the limiting factors of base saturation, organic carbon content, coarse materials, and erosion hazards persist.

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