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Assessment of Soil Quality Index Based on Chemical Properties at Various Land Use and Criticality Levels

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ABSTRACT

Land damage will reduce the quality of land function and increase the area of critical land. Land use in the Manten Subwatershed cause changes land function that have the potential to increase the criticality level of a land. This study aims to measure the soil quality index from the chemical aspect of critical land in the Manten Subwatershed. Surveys at sampling points were conducted on three types of land use (kaleyard, rice fields, and dry fields) combined with three levels of critical conditions (not critical, critical, and potentially critical). Each combination was carried out at three locations, involving 27 sampling points. Soil quality indicators measured in terms of chemistry include soil pH, nitrogen, phosphorus, potassium, and soil organic matter content. The results of the study showed that all sampling points had a very low soil quality index with an SQI score between 0.06 and 0.122 and an average pH that tended to be low (<6), N-total content of 0.137%-0.308%, phosphorus of 70.97-655.66 ppm, exchangeable potassium of 0.490-2.690 me/100 g, and organic matter 0.023%-0.044%. The practice of adding organic matter needs to be implemented to improve soil quality.

1. INTRODUCTION

Soil is a component of land that functions in life as a producer of biomass that supports the sustainability of living things. Land use needs to pay attention to physical factors of the land such as land capability and suitability in order to avoid negative impacts on the soil. Land that is used inappropriately without taking into account the condition and capability of the land will have a negative impact on the soil (Bashit, 2019). Soil quality is the capacity of the soil to maintain soil productivity and maintain the availability of groundwater to support agricultural activities (Hamdi *et al*., 2021). The soil quality index is an index or value calculated from the weight of each soil quality indicator that can describe the condition of a soil (Pratoyo, 2005). Soil quality indicators are a combination of physical, chemical, and biological properties of the soil that can be applied to various land conditions. According Sholihah *et al*. (2016) soil quality indicators must be sensitive to climate change and soil management. The soil quality index can be used to assess the impact of land management activities. Land management should be adjusted to the needs and capabilities of a land so as not to reduce the quality and productivity of a land which in turn causes critical land (Bashit, 2019). Differences in land use involving different soil processing can affect soil properties, both physically, chemically, and biologically (Delsiyanti *et al*., 2016).

The ecosystem of a watershed is divided into three parts, namely upstream, middle, and downstream. The upstream area as a water provider is generally a forest area (Azwarman, 2020). Sub-watersheds are parts of the watershed that receive rainwater and then distribute it through tributaries to the main river (Gultom *et al*., 2022). Critical land is a land area located inside or outside the watershed area that has been damaged so that its function is lost or reduced to a specified limit (Wardiman *et al*., 2020). In general, critical land is one indicator of environmental degradation as a result of various types of unwise use of land resources. The main characteristics of critical land are bare, appear arid, and even rocks appear on the surface of the ground, and are generally located in areas with hilly or steep sloping land topography (Bashit, 2019).

The Manten Subwatershed is one of the important subwatersheds in the Brantas Watershed located in Malang Regency. Based on data obtained from the Forestry Service, land use in the Manten Subwatershed is dominated by agricultural lands, open lands, kaleyards, and small parts are building land, shrubs, mixed gardens and water bodies (Dinas Kehutanan Provinsi Jawa Timur, 2019). Inappropriate land use in the Manten Subwatershed can cause land degradation which has the potential to increase the level of land criticality. Decreased land productivity on critical land causes land damage and decreased soil fertility, thereby reducing the value of the soil quality index on the land. Therefore, sustainable watershed management is needed to reduce the increasingly high land degradation (Yumansyah *et al*., 2021). This study aims to analyze soil quality index due to various types of land use and land criticality levels in the Manten Subwatershed based on soil chemical property parameters. The results of the study are expected to be used as a basis and reference for farmers and local governments in land management in the Manten Subwatershed.

2. MATERIALS AND METHODS

2.1. Research Time and Location

This research was conducted in the Manten sub-watershed located in the upper part of the Brantas watershed adjacent to the Lesti sub-watershed. The soil sample was tested in the laboratory of the Faculty of Agriculture, Universitas Pembangunan Nasional "Veteran" East Java. The materials included land use map of Malang District, land criticality map of Manten sub-watershed, Land Use Unit (SPL) map, and soil samples. The analysis in this research was based on Mausbach & Seybold (1998). Soil quality was assessed using SQI (Soil Quality Indeks) through data scoring on each measured parameter.

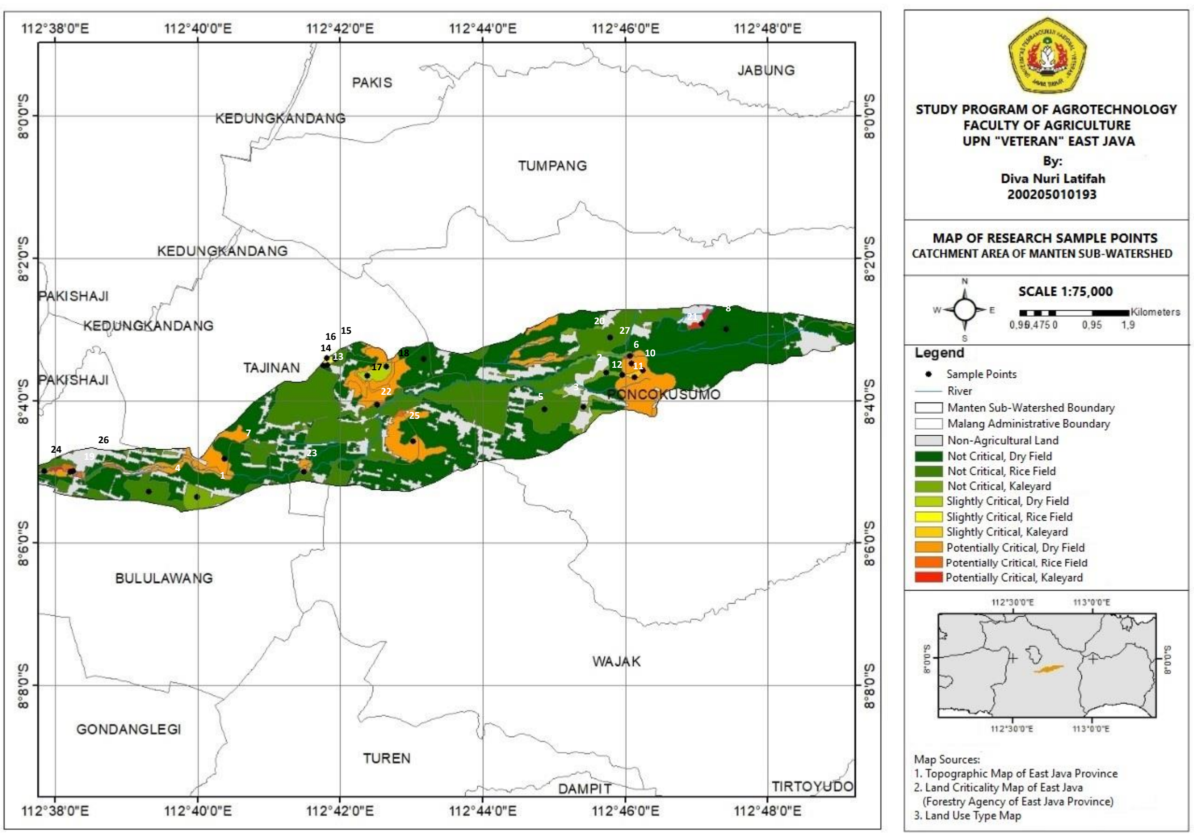

Figure 1. Map of sample point distribution (numbers of sampling point are according to the order in Table 1)

Determination of sampling points was carried out purposively based on the Land Use Unit and the level of land criticality. Three land use units were selected including rice field, kaleyard, and dry field. Each land use type was analyzed based on criticality levels, including uncritical, critical, and potentially critical. Critical condition of lands was based on data published by Forestry Service, East Java Province (Dinas Kehutanan Provinsi Jawa Timur, 2019). Sampling points were taken at three different locations, resulted in a total of 27 sample points detailed in Table 1. Soil sampling was carried out at a depth of 0-30 cm and 30-60 cm and a composite soil was used for analysis. The soil chemical parameters included pH, total nitrogen (N-total), exchangeable potassium (K-exc), available phosphorus (P-available), and organic carbon (C-organic). Table 2 lists the soil chemical parameters and the analytical methods used.

Table 1. The 27 sampling points involving three land use units and three criticality levels

No	Land Use	Critical Level*	Sample Code	No. in Map	Coordinate		Area (ha)
					Longitude	Latitude	
1	Kaleyard	Not Critical	KTK1	1	112°39'60"	8°05'22"	473,274.21
			KTK2	2	112°45'42"	8°03'37"	
			KTK3	3	112°49'05"	8°02'57"	
2	Rice field	Not Critical	STK1	4	112°39'31"	8°05'14"	322,659.38
			STK2	5	112°42'44"	8°04'05"	
			STK3	6	112°45'59"	8°03'08"	
3	Dry field	Not Critical	LTK1	7	112°39'59"	8°05'06"	658,444.51
			LTK2	8	112°46'30"	8°03'23"	
			LTK3	9	112°49'06"	8°03'04"	
4	Kaleyard	Slightly Critical	KAK1	10	112°46'15"	8°03'35"	1,786.99
			KAK2	11	112°46'08"	8°03'40"	
			KAK3	12	112°45'58"	8°03'38"	
5	Rice field	Slightly Critical	SAK1	13	112°41'49"	8°03'30"	9.60
			SAK2	14	112°41'49"	8°03'24"	
			SAK3	15	112°41'56"	8°03'25"	
6	Dry field	Slightly Critical	LAK1	16	112°41'46"	8°03'30"	531.79
			LAK2	17	112°42'39"	8°03'31"	
			LAK3	18	112°42'23"	8°03'39"	
7	Kaleyard	Potentially Critical	KPK1	19	112°37'51"	8°04'59"	30,358.61
			KPK2	20	112°46'04"	8°03'22"	
			KPK3	21	112°47'04"	8°02'55"	
8	Rice field	Potentially Critical	SPK1	22	112°38'15"	8°04'59"	3.464.95
			SPK2	23	112°42'32"	8°04'03"	
			SPK3	24	112°45'10"	8°03'24"	
9	Dry field	Potentially Critical	LPK1	25	112°38'13"	8°04'60"	12.292.18
			LPK2	26	112°42'46"	8°04'22"	
			LPK3	27	112°46'05"	8°03'29"	

*) Critical condition was based on Dinas Kehutanan Provinsi Jawa Timur (2019)

Table 2. Observation parameters and analysis methods

Number	Parameters	Unit	Analysis Method
1	pH	-	pH meter
2	N Total	mg/kg	Kjeldahl
3	P-available	mg/kg	Olsen & Bray I
4	K-exchangeable (K-exc)	me/100 g	Ammonium Acetate Extract
5	C-organic	mg/kg	Walkey & Black

2.3. Data Analysis

The observation parameters focused on soil chemical properties that are indicators of soil quality based on the method from Mausbach & Seybold (1998). Assessment of soil quality used SQI through data scoring on each parameter. The calculation of soil quality was done by multiplying the weight index based on the table above with the score of the indicator obtained from laboratory analysis. The weight index was calculated by multiplying the weight of soil function (weight 1) by the weight of rooting medium (weight 2) and by the weight of rooting depth (weight 3).

Table 3. Indicators, weights, and weight index for soil quality assessment in terms of chemical properties

Land Function	Weight	Indicator	Weight	Weight	Weight Index	Assessment Function			
						Lower limit		Upper Limit	
	1		2	3	(1×2×3)	x_1	y_1	x_2	y_2
Preserving biological activities	0.4	Stiffness	0.33						
		C-organic (%)		0.4	0.053	0.2	0	3.5	1
		Nutrient	0.34						
		pH		0.1	0.013	6.0	0	8.0	1
		P-availability (ppm)		0.2	0.026	2.50	0	150	1
		K-exc. (me/100 g)		0.2	0.026	2.22	0	35.5	1
		C-organic (%)		0.3	0.040	0.20	0	3.5	1
		N Total (%)		0.2	0.026	0.02	0	0.10	1
Filters and Buffering	0.3	Microbiological Process	0.3						
		C-organic (%)		0.33	0.03	0.2	0	3.5	1
		N Total (%)		0.33	0.03	0.04	0	0.07	1

Scores were calculated by comparing observed data from soil indicators and assessment functions. Scores range from 0 for poor condition to 1 for good condition. Scores were assigned through interpolation or linear equations according to the range of data obtained. The score was calculated as the following (Nurhutami *et al*., 2020):

$$F(x) = y_1 + (x - x_1)\left(\frac{y_2 - y_1}{x_2 - x_1}\right) \tag{1}$$

where x is observation value, x_1 is lower limit of the scoring function, x_2 is upper limit of scoring function, y_1 is lower limit of the assessment function, and y_2 is upper limit of the assessment function.

The soil quality index was calculated by multiplying the weight index and score of the indicator. Soil quality assessment used the soil quality index equation as the following (Liu *et al*., 2014):

$$SQI = \sum_{i=1}^{n} W_i \times S_i \tag{2}$$

where SQI is soil quality index, S_i is score of selected soil indicators, n is total soil indicators, W_i is weighting index.

Table 4. Soil quality index values and soil quality criteria (Hamdi *et al*., 2021)

SQI Value Class	0.80 – 1.00	0.60 – 0.79	0.40 – 0.59	0.20 – 0.39	0.00 – 0.19
Soil Quality Criteria	Very good	Good	Medium	Low	Very low

3. RESULTS AND DISCUSSION

Manten Subwatershed is one of the subwatersheds with tributaries of the Brantas River, which has an important role in draining water and supporting ecosystems and human life around it (Cahyono *et al*., 2020). Based on data from the Dinas Kehutanan Provinsi Jawa Timur (2019), Manten Subwatershed is located in 4 sub-districts in Malang Regency, namely Bululawang, Poncokusumo, Tajinan, and Wajak. The area is located at 112°37'-112°49' East Longitude and 8°02'-8°04' South Latitude with an elevation of 700-800 m above sea level. Manten Subwatershed is a watershed as a provider of water that can be utilized by the community for consumption and agricultural purposes. Sub-watershed has an important role in the management of water resources and aquatic environment (Gultom *et al*., 2022). Area expansion in the form of land conversion, both into settlements and agricultural land in the process often does not pay attention to the rules of soil and water conservation. Therefore, sustainable catchment management is needed to reduce the increasing land degradation (Yumansyah *et al*., 2021). Table 1 summarizes chemical properties of the soils in the Manten Subwatershed.

Table 5. Contents of total nitrogen (N-total), available phosphorus (P-available), exchangeable cations (K-exc), organic carbon (C-organic), and soil pH based on land use types and land criticality levels

No	Sample Code	N-total (%)		P-available (ppm)		K-exc (me/100 g)		C-organic (%)		pH		Soil Quality Index		
		Obs.	Ave.	Obs.	Ave.	Obs.	Ave.	Obs.	Ave.	Obs.	Ave.	Obs.	Ave.	Criteria
1	KTK1	0.225		109.09		1.098		0.039		5.090		0.092		
	KTK2	0.360	0.308	216.98	117.26	0.952	1.182	0.035	0.037	5.950	5.42	0.157	0.122	Very low
	KTK3	0.340		25.72		1.496		0.038		5.240		0.116		
2	STK1	0.215		237.08		1.399		0.031		6.395		0.112		
	STK2	0.260	0.255	157.67	164.39	1.318	1.420	0.031	0.032	5.635	6.12	0.113	0.112	Very low
	STK3	0.290		98.42		1.544		0.035		6.335		0.112		
3	LTK1	0.265		39.68		1.692		0.037		5.635		0.093		
	LTK2	0.410	0.298	82.37	130.92	2.089	1.803	0.053	0.043	5.550	5.32	0.148	0.120	Very low
	LTK3	0.220		270.71		1.626		0.040		4.785		0.119		
4	KAK1	0.315		443.25		1.692		0.042		5.655		0.181		
	KAK2	0.210	0.238	855.30	655.66	1.244	1.338	0.031	0.033	5.855	5.79	0.219	0.193	Very low
	KAK3	0.190		668.44		1.077		0.027		5.860		0.180		
5	SAK1	0.160		90.25		3.617		0.023		6.510		0.068		
	SAK2	0.240	0.202	238.65	125.42	3.336	2.690	0.032	0.029	6.170	6.20	0.121	0.088	Very low
	SAK3	0.205		46.36		1.118		0.032		5.915		0.075		
6	LAK1	0.125		215.53		0.588		0.024		7.305		0.080		
	LAK2	0.080	0.137	16.06	85.70	2.145	1.603	0.017	0.023	6.255	6.48	0.030	0.060	Very low
	LAK3	0.205		25.50		2.075		0.027		5.890		0.071		
7	KPK1	0.210		118.07		0.612		0.027		6.035		0.090		
	KPK2	0.245	0.213	124.01	144.55	0.277	0.490	0.037	0.030	4.850	5.72	0.102	0.096	Very low
	KPK3	0.185		191.58		0.580		0.025		6.290		0.095		
8	SPK1	0.300		127.09		0.386		0.036		6.525		0.121		
	SPK2	0.210	0.277	162.56	212.52	1.443	1.081	0.032	0.030	6.215	6.32	0.097	0.112	Very low
	SPK3	0.170		347.90		1.413		0.021		6.215		0.117		
9	LPK1	0.140		10.82		2.117		0.021		6.055		0.048		
	LPK2	0.265	0.307	63.98	70.97	2.538	2.376	0.038	0.044	6.315	5.46	0.097	0.112	Very low
	LPK3	0.515		138.11		2.471		0.072		4.000		0.193		

Description: KTK = Uncritical Kaleyard; STK = Uncritical Rice Field; LTK = Uncritical Dry Field; KAK = Slightly Critical Kaleyard; SAK = Slightly Critical Rice Field; LAK = Slightly Critical Dry Field; KPK = Potentially Critical Kaleyard; SPK = Potentially Critical Rice Field; LPK = Potentially Critical Dry Field.

3.1. Total Nitrogen

Figure 2 shows the total nitrogen (N-total) content in the soil for all 27 sampling points. Total nitrogen describes the content of all nitrogen in the soil both in available form and in the form that is still integrated as organic compounds (Lisa *et al*., 2022). The results of the measurement show the highest N-total value was obtained in the uncritical kaleyard land use (KTK) with average of the three sampling points reached Kaleyard with slightly critical (KAK) and potentially critical (KPK) have average N-total value of 0.238% and 0.213%, respectively. Meanwhile, the lowest N-total value was obtained in the land use of dry fields with a level of criticality that is slightly critical (LAK), reaching an average of 0.137% with a range of 0.080% to 0.205%. Land use type of rice field showed average N-total value of 0.255% for uncritical condition (STK), 0.202% for slightly critical (SAK), and 0.277% for potentially critical (SPK). Overall, the highest N-total value was obtained in the kaleyard land use type with a criticality level of uncritical (KTK). This relates to the vegetation condition in the kaleyards which is quite dense. The soil under the vegetation continuously receives organic N supply from leaves, twigs and other plant residues (Rosalina & Maipauw, 2019).

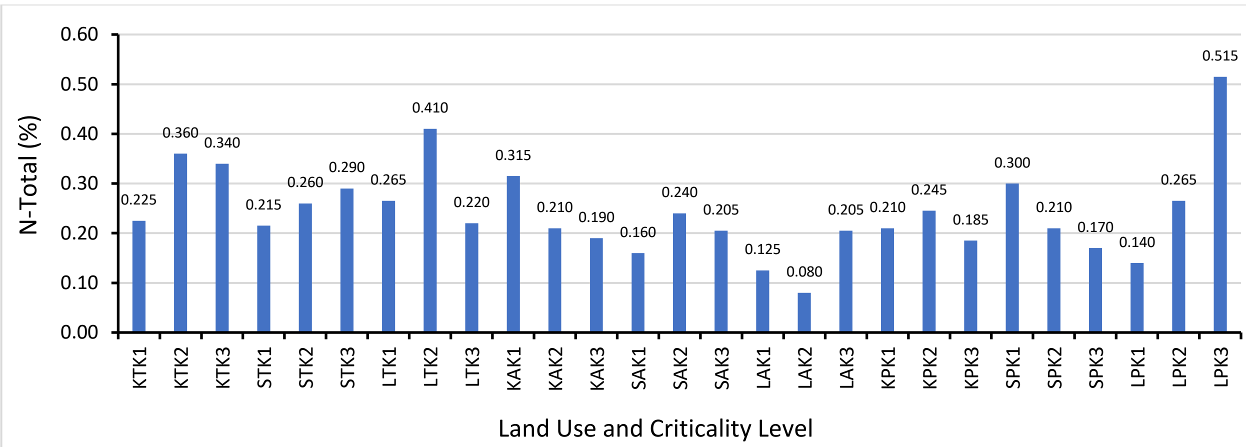

Figure 2. Distribution of N-total in the soil for 27 sampling points

3.2. Available Phosphorus

The results of the measurement of the highest P-available value were obtained in the land use of kaleyard with a slightly critical level (KAK). The average of the three sampling points reached 655.664 ppm (Figure 3), with the highest P-available at point KAK2 and the lowest at point KAK1. While in the land use of kaleyard with criticality status uncritical (KTK) and potentially critical (KPK) the average P-available results were 117.265 ppm and 144.558 ppm, respectively. Meanwhile, the lowest P-available value was obtained in the land use of dry fields with a criticality level of slightly critical (LAK), reaching an average of 85.701 ppm with the lowest value obtained at point LAK2 (16.067 ppm). In other types of use, namely rice fields, the average value of P-available was 164.394 ppm for criticality level of uncritical (STK), 125.423 ppm for alightly critical (SAK), and 212.522 ppm for potentially critical. The lowest P-available value for rice field was 46.360 ppm from SAK3 and the highest of 347.904 ppm from SPK3. Overall, the highest P-available value was obtained in the land use type of slightly critical kaleyard.

According to Jayadi *et al*. (2022) variations in P-available levels in soil are due to land management. Land management such as the addition of high P fertilizer can increase the value of P-available in the soil. Results of our study indicates that all land use types and all critical levels in the Manten Subwatershed neglect the sustainable agricultural practices. This is in accordance with Tuhehay *et al*. (2019) stating the main cause of critical land in the study area is due to agricultural activities that do not pay attention to aspects of land sustainability, including intensive chemical fertilizer addition activities. In addition to the release of residues, the high P content in the soil comes from the dissolution of chemical fertilizers given to the soil so that the available P becomes very high (Pakpahan & Guchi, 2019). Too high P content in the soil can cause residue accumulation in the soil (Jayadi *et al*., 2023).

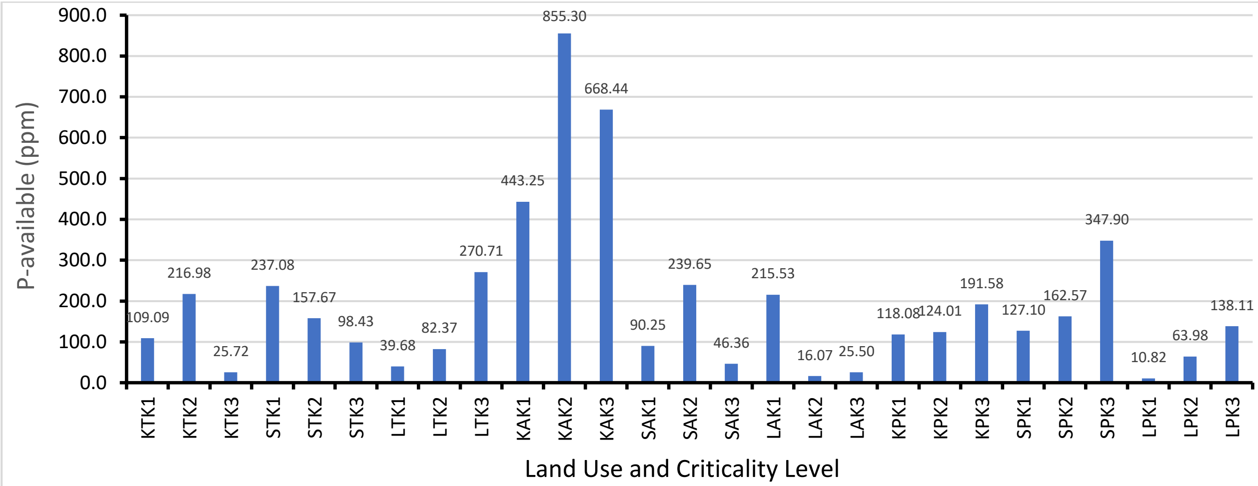

Figure 3. Distribution of P-available in the soil for 27 sampling points

3.3. Exchangeable Cations (K-exc)

Figure 4 portrait exchangeable cations resulted from the 27 sampling points in the study area. The measurement results of the exchangeable cations value calculated on the element potassium (K) with the highest results obtained in the use of rice fields with a level of criticality of slightly critical (SAK). The average at the three land use points reached 2.690 me/100 g, with the highest K-exc value at point SAK1 and the lowest at point SAK3. While at the land use of unritical rice fields (STK) and potentially critical rice fields (SPK) the average K-exc results were 1.420 me/100 g and 1.081 me/100 g, respectively. Meanwhile, the lowest K-exc value was obtained in the land use of kaleyard with potentially critical level, which reaches an average of 0.490 me/100 g with the lowest value obtained at the KPK2 point (0.277 me/100 g) and the largest at the KPK1 point which reaches 0.692 me/100 g. For the dry fields, the average K-exc value of was 1.803 me/100 g for uncritical level (LTK), 1.603 me/100 g for alightly critical (LAK), and 2.376 me/100 g for potentially critical. Overall, the highest K-exc value was found in the slightly critical rice field (SAK) land use type.

Based on the criteria for assessing soil chemical properties (Batubara *et al*., 2024), exchangeable K content < 0.1 is very low, 0.1 - 0.3 is low, 0.4 - 0.5 is medium, 0.6 - 1.0 is high, and > 1.0 is very high. It can be concluded that all types of land use observed have high available K. Low potassium in potentially critical kaleyard is likely to occur due to different weathering and leaching times in each land use type. Siswanto *et al*. (2024) stated that the levels of available K in each land are always different with different depths. This is because each soil depth has different soil pH, weathering time, texture, and leaching in each land use. Exchangeable K is bound by negative mutants of soil colloids and humus.

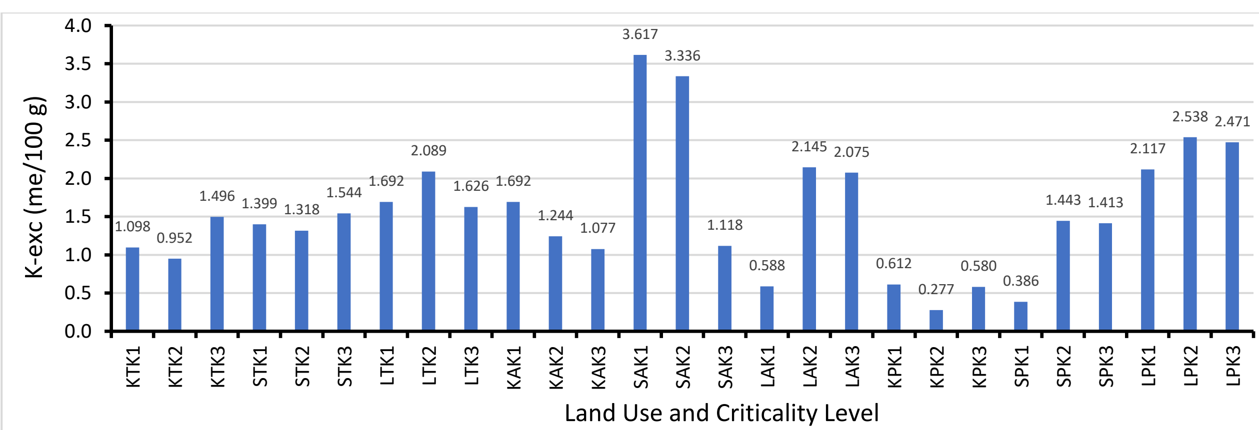

Figure 4. Distribution of K-exchangeable in the soil for 27 sampling points

Potassium is one of the most active exchange cations in the soil besides Ca, Mg, Na, Al and H. Potassium bound to soil colloids will exchange with other ions due to the CEC (cation exchange capacity) properties of the soil, as a result K will be released from its bonds and occupy the soil solution into the form of available K (Al Mu'min *et al*., 2016).

Overall, the highest K-exc value is obtained in the type of land use of rice fields with a criticality level of slightly critical (SAK) due to inundation in paddy fields. Inundation contributes to the provision of K elements in the soil. Inundation will basically increase the concentration of K in the soil solution under reducing conditions. Usually Fe^{2+} and NH_4^+ are liberated through various processes and the transfer of K^+ occurs from the exchange complex, so that its concentration increases in the soil solution and becomes more available to plants in rice fields (Erpan, 2012).

3.4. Carbon Organic

The results of the measurement as depicted in Figure 5 revealed the highest C-organic value was obtained in the potentially critical dry fields (LPK). The average C-organic of the three land use points reached 0.044% followed by the uncritical dry field of 0.043%. Slightly critical dry fields (LAK) have the lowest average C-organic with average of 0.023%. Meanwhile, the C-organic value in the land use of kaleyard was 0.037% for uncritical level (KTK), 0.033% for slightly critical (KTK), and 0.030% for potentially critical (KPK). For rice fields, the average value of C-organic was 0.032% for uncritical level (STK), 029% for slightly critical (SAK), and 0.030% for potentially critical rice fields (SPK).

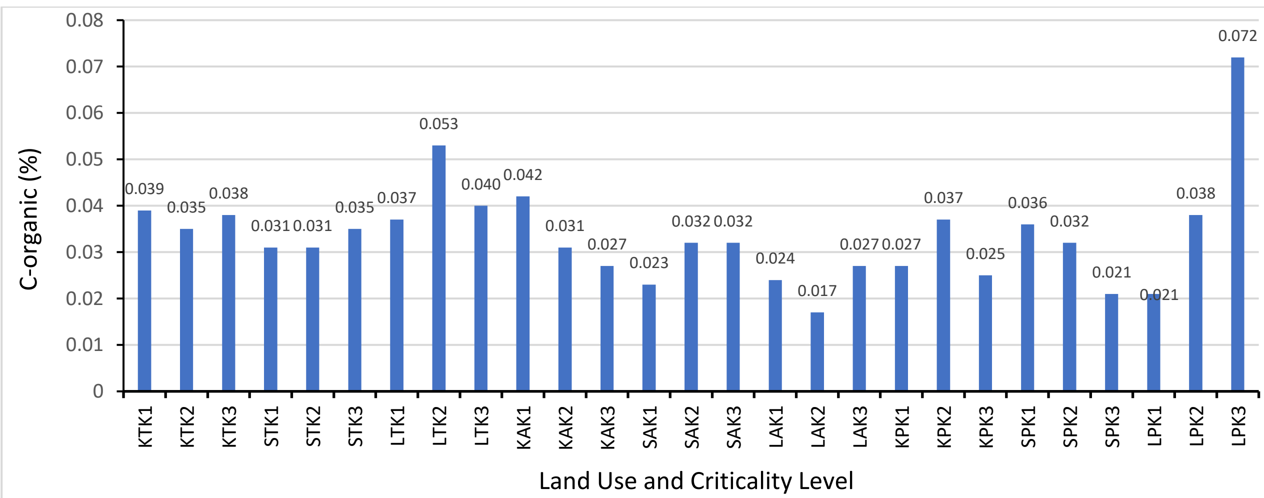

Figure 5. Distribution of C-organic in the soil for 27 sampling points

C-organic values in all types of land use fall into the very low category. C-organic is said to be very low when it is at a value of < 1%. Jasmine (2016) mentioned that organic C of <1% is very low, 1%–2% is low, 2%–3% is medium, >3% is high. The low C-organic is resulted from the low organic matter in the soil. C-organic value has a positive relationship with the value of organic matter. If the organic matter is high, the C-organic value is also high. This is because C-organic is organic is a constituent component in organic matter. Soils that have low C-organic or organic matter may experience an imbalance between the role of organic matter and the loss of organic matter from the soil through biological oxidation processes in the soil. Erosion of topsoil which is rich in organic matter also plays a role in reducing the organic matter content of the soil.

The low C-organic in the overall land use observation is also caused by climatic factors. Soil sampling was conducted during the rainy season and the day after the rain. Climatic conditions, especially rainfall, affect the condition of C-organic in the soil. C-organic on the soil surface can be leached by rainwater runoff. This is in line with the opinion of Utomo *et al*. (2016) that C-organic levels in the soil are susceptible to being lost due to erosion due to high rainfall. Nurhasni & Isrun (2021) state that low soil pH will cause nutrient availability to decrease and the breakdown of organic matter is inhibited. C-organic is the main constituent component of organic matter.

3.5. Soil pH

Soil pH is an indicator of soil fertility that indicates the availability of nutrients in the soil. Soil pH is an important factor that affects the process of nutrient absorption by plant roots. Soil pH is very important because the soil solution contains nutrients that plants need to grow, develop, and defend against disease.

The results of the measurement of the highest soil pH value (Figure 6) was obtained in the land use of slightly critical dry fields (LAK). The average pH in this land use reached 6.48 with the lowest of 5.32 found in uncritical dry field (LTK). In the land use of kaleyard with a criticality level of uncritical (KTK), the soil pH reached 5.42. Slightly critical kaleyard (KAK) has soil pH of 5.79, and potentially critical one (KPK) only reached pH of 5.72. In other types of land use, namely rice fields, the average pH value was 6.12 uncritical level (STK), 6.19 for slightly critical rice fields (SAK), and 6.31 for potentially critical rice fields (SPK).

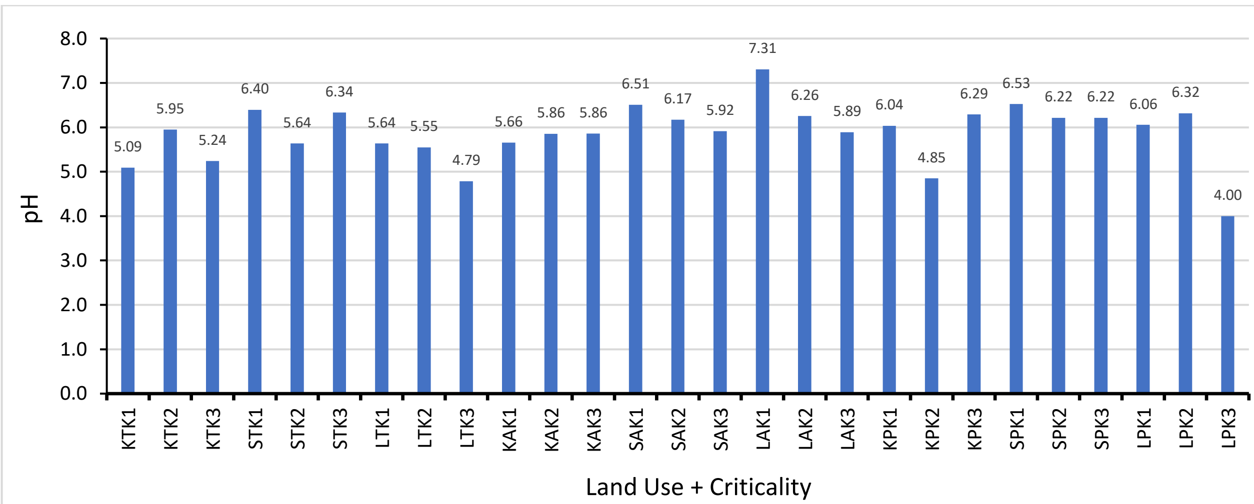

Figure 6. Distribution of soil pH for 27 sampling points in the Manten Subwatershed

Nutrients can generally be absorbed well by plants at neutral pH. However, based on Table 5, it can be seen that all types of land use observed are classified as acidic because they have a pH <7 (Nazir *et al*., 2017). The low pH is caused by the low C-organic in the observation location. The lower the C-organic value in the soil, the lower the soil pH value (Karnilawati *et al*., 2022). In addition, low pH values are often influenced by Al and Fe ions which are toxic to plants.

High rainfall at the time of sampling also affected the pH value at the study site. High rainfall results in the dissolution and washing away of basic cations from the sorption complex and what is left behind are cations that have the ability to bind strongly with soil colloids such as aluminum (Al). The amount of Al-exc absorbed on the surface of soil colloids can cause hydrolysis, which contributes H^+ ion in large quantities, so that the soil reacts acidic (Syofiani *et al*., 2020).

3.5. Soil Quality Index of Soil Chemical Properties

According to Jawang & Ndapamuri (2023) soil quality indicates the ability of soil to support plant productivity, plant quality, and water availability for plant and human needs. Wulandari & Khayah (2015) explained that soil quality can fluctuate, both increase and decrease, which can be observed through changes in soil properties, including chemical, physical, and biological aspects. Each region has unique soil quality characteristics, which can be influenced by the type of soil and tillage methods applied. A soil quality index is a measure calculated based on the values and weights of various soil quality indicators. Soil quality assessment can also be done by observing changes in soil function in response to management, taking into account factors such as land use, soil inherent properties, and environmental influences such as rainfall and temperature. Based on the calculation results of the Soil Quality Index value (Table 5 and Figure 7) reviewed from the chemical properties, the catchment area in the Manten Subwatershed with land use types of dry fields, kaleyards, and rice fields, are all classified as very low (VL). Based on calculation performed in the 27 sampling points, a map of soil quality index is presented for the Manten Subwatershed (Figure 8). Soil as a place for biological activity has several indicator functions that support biological activity, namely moisture and nutrient. Determination of the soil indicator function is carried out using several soil parameters. In this study, the moisture indicator function is determined by the C-organic parameter, the filter and buffering function is determined by C-organic and N-total. While the nutrient function is determined by the parameters of soil pH, P-available, K-exc, C-organic, and N-total.

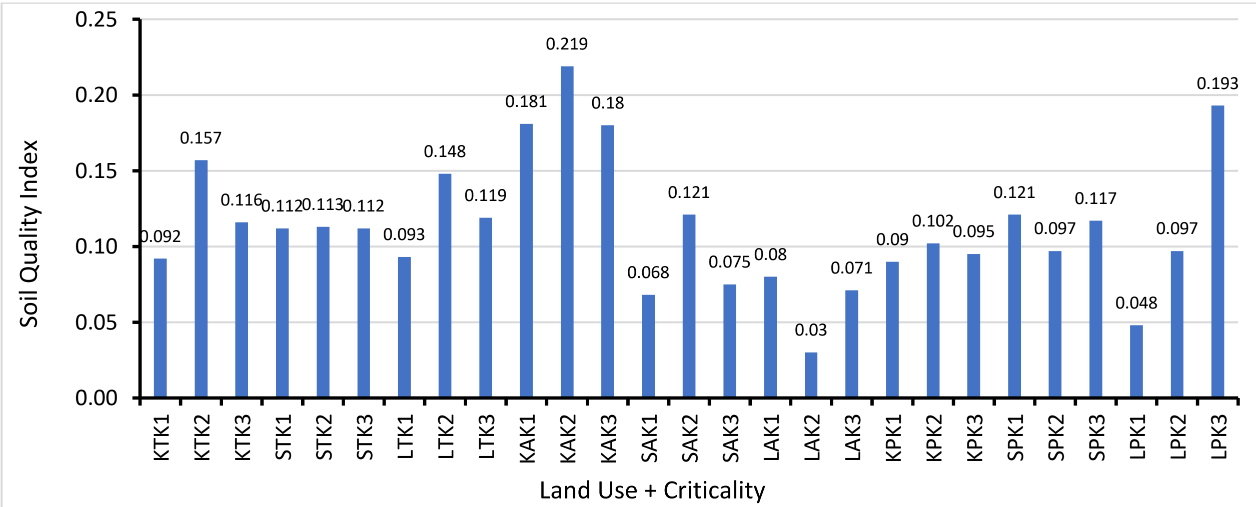

Figure 7. Distribution of soil quality index for 27 sampling points in the Manten Subwatershed

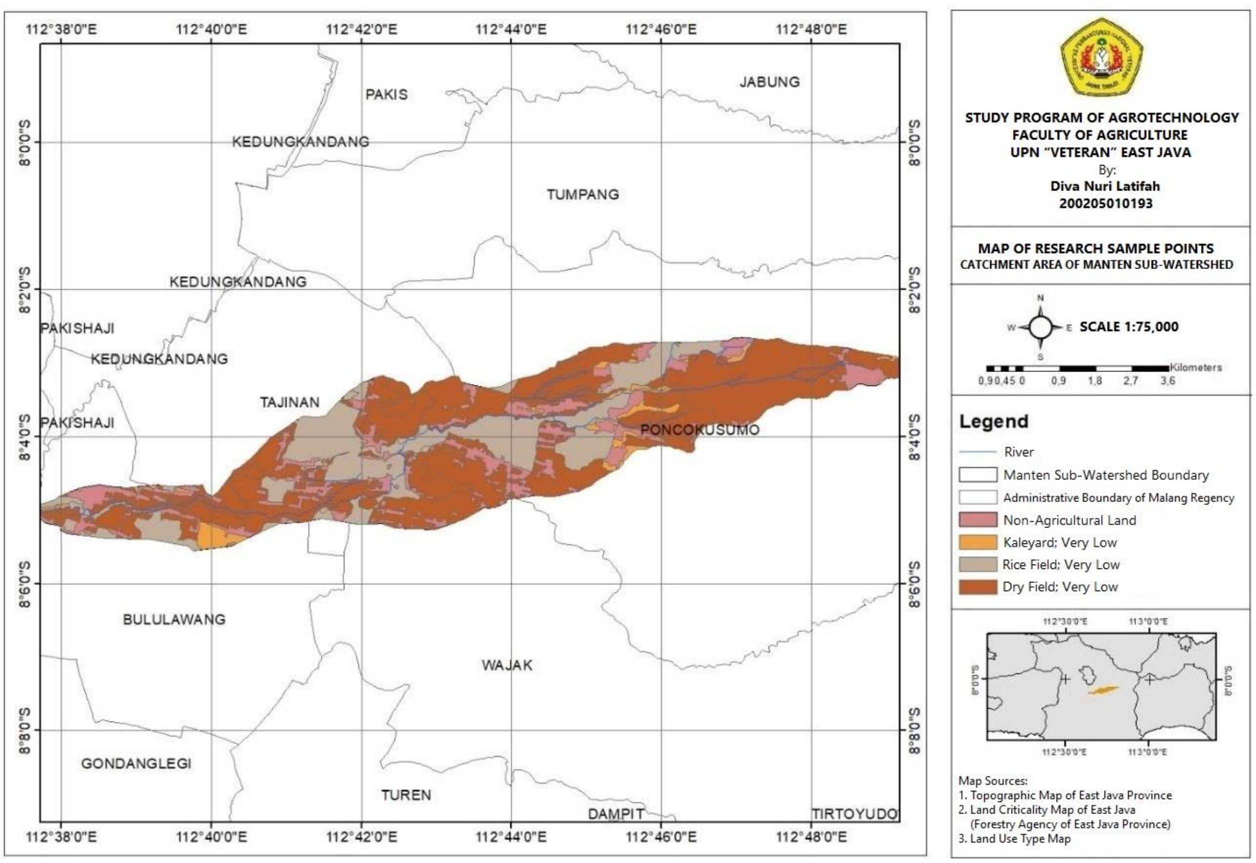

Figure 8. Map of Soil Quality Index for the Manten Subwatershed

The Soil Quality Index is influenced by limiting factors in the form of soil chemical property indicators, namely C-organic, P-available, and pH. The results of the study showed that all types of land use studied had an average of low C-organic and pH, and P-available which was too high. The content of soil organic matter is generally used as an indicator of soil quality and the abundance of essential mineral elements (White *et al*., 2014). The low organic matter or C-organic at the research location made the soil quality index value very low. The C-organic content at the research location only ranged from 0.023-0.044%. This is in line with Kurniawan *et al*. (2021) which stated that organic matter plays an important role in determining soil quality. The lower the organic matter in the soil, the lower the soil quality index. Critical lands experience physical, chemical and biological damage caused by management and use that is not in accordance with its capabilities, thus impacting agricultural production, hydrological functions, socio-economic life, and the environment (Zachrani *et al*., 2024). Although classified as non-critical, the use of kaleyards, dry fields, and rice fields in observations has a very low SQI. Factors that cause low SQI values on non-critical land can be caused by low values of soil quality determining indicators (Kurniawan *et al*., 2021).

3.6. Improvement Efforts

Soil improvement efforts on low-quality land can be done by focusing on improving soil chemical indicators that are limiting. Efforts to increase C-Organic levels at the research site which is classified as very low can be through the addition of organic matter to the soil. Based on the research of Afandi *et al*. (2015) organic matter in the form of chicken manure, cow dung and compost has a significant effect on soil C-organic content. According to Utami & Handayani (2003) the addition of organic matter can increase soil C- organic content, which in turn can improve soil physical, chemical, and biological properties. Organic matter can also increase soil cation exchange capacity, soil pH, P nutrient, and crop yields (Pane *et al*., 2014). The results showed that all land uses (rice fields, dry fields, and kaleyards) with all criticality levels (uncritical, slightly critical, and potentially critical) have an average pH <6. Increasing pH through the addition of organic matter occurs through the decomposition process of rice husk biochar into the soil.

Another practical effort that can be made to improve soil quality is through amelioration, which is a soil amendment. Soil amelioration can be done in various ways starting from applying organic fertilizers such as manure, compost and biochar from agricultural waste. One solution to overcome the high levels of phosphorus in the soil of the Manten Sub-watershed area is to reduce the use of chemical fertilizers, especially those containing phosphorus elements. According to research by Pahlepi *et al*. (2023) excessive use of chemical fertilizers can result in several negative impacts including reduced populations of soil microorganisms and decreased plant resistance to pests and diseases, Furthermore, unbalanced application of chemical fertilizers can increase plant susceptibility to plant pest organisms, cause a decrease in productivity that is not in accordance with the genetic potential of the variety, inhibit plant growth (stunted), and trigger premature flowering. In addition, the continuous and long-term use of chemical fertilizers has the potential to damage groundwater quality, which in turn can result in decrease in soil fertility. The implementation of appropriate farmland management practices has the potential to significantly improve soil quality.

4. CONCLUSION

The soil quality index on all types of land use in the catchment area of Manten Sub Watershed, namely fields, rice fields and gardens with the level of criticality is not critical, slightly critical and potentially critical is very low with a range of Soil Quality Index values of 0.060 to 0.193. Some land uses with criticality are not critical, slightly critical, and potentially critical in the catchment area of Manten Sub Watershed has very low soil quality. Proper and appropriate land treatment is needed to improve soil quality in order to prevent non- critical land from turning to mildly critical by adding soil organic matter and increasing soil pH by adding dolomite. Based on the results of the soil quality index research in terms of chemical properties, it is necessary to conduct further and comprehensive research in determining the Soil Quality Index in the Manten Subwatershed catchment area in terms of various soil properties, namely physical, chemical, and biological properties of soil.

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