Bulgarian Journal of Agricultural Science, 29 (No 5) 2023, 805–812

Evaluation of soil quality index in different types of land use for *Theobroma cacao* L. development in Kebonagung subdistrict, Pacitan district

Suko Irawan, Slamet Minardi and Supriyadi*

Sebelas Maret University, Department of Soil Science, Faculty of Agriculture, 57126, Surakarta, Indonesia
**Corresponding author:* supriyadi_uns@yahoo.com

Abstract

Irawan, S., Minardi, S. & Supriyadi (2023). Evaluation of soil quality index in different types of land use for *Theobroma cacao* L. development in Kebonagung subdistrict, Pacitan district. *Bulg. J. Agric. Sci., 29*(5), 805–812

This study aims to determine the soil quality index (SQI) on existing cocoa in various soil types and provide recommendations for improving cocoa productivity. The research was conducted in Kebonagung District, Pacitan Regency, East Java using an exploratory, descriptive method through a survey approach. Determination of land map unit (LMU) was obtained through an overlay of maps of soil type, land use, slope, geology, and rainfall. The survey area consists of 10 LMU repeated three times. Soil samples were analyzed for physical, chemical, and biological properties in the laboratory. Principal Component Analysis (PCA), was used to analyze data and to obtain the Minimum Data Set (MDS). Soil Quality Index (SQI) at each LMU, was calculated by calculating the PCA result score (Wi), with the score for each selected indicator (Si). Moor has a low-quality class (0.32), while rice fields (0.40) and secondary forest (0.39) have a medium class. The indicators that become the limiting factor of soil quality based on the correlation test results are pH, CEC, and K-Available. Based on the limiting factors obtained, recommendations for improvement are by giving dolomite and captan, cocoa husk compost, and KCL balanced fertilization.

Keywords: soil quality; moor; rice field; secondary forest; principal component analysis

Introduction

Since 1930, Cocoa (*Theobroma cacao* L.) has been one of the plantation commodities that has an important role in improving the Indonesian economy. In 2010, Indonesia was the world's third-largest exporter of cocoa beans with a production of 550 000 tons of dry beans after Ivory Coast (1 242 000 tons) and Ghana with a production of 662 000 tons (ICCO, 2011). Unfortunately, Indonesia's cocoa production has continued to decline since 2015, causing Indonesia's position as the world's fifth-largest cocoa producer to be displaced by Ecuador and Nigeria in 2017 (UNIED, 2019). The increasing demand for cocoa beans, especially from the United States and Western European countries, is an opportunity that must be maximized. Indonesia as a producer needs to take advantage of this opportunity to increase the country's foreign exchange by increasing cocoa bean exports. Oriented to the export market, the big opportunity for Indonesian cocoa is still relatively open. Based on BPS, (2020), in 2017, the total value of cocoa exports reached US$1.12 billion. The Ministry of Agriculture has determined cocoa as one of the leading commodities in agricultural development in 2015-2019, and rubber, oil palm, coconut, coffee, pepper, and other commodities (BPS, 2020a). The target for cocoa production growth rate is set at 3.9% per year. Based on Kepmentan No. 511/2006 concerning Types of Plant Commodities fostered by the Directorate General of Plantations, the Directorate General of Food Crops, and the Directorate General of Horticulture, as well as Decree of the Minister of Agriculture No. 3599/2009 concerning Amendments to Attachment I of Kepmentan No. 511/2006, cocoa is one of the 16 leading plantation commodities that are the focus of development. Developing these commodities is achieved through a program to increase the production of sustainable plantation commodities by implementing activities, such as rehabilitation, intensification, extensification, and diversification, supported by the provision of quality seeds. Unfortunately, the cocoa production improvement program implemented by the government has not been successful, as indicated by the development of cocoa bean production, which continued to decline after 2010 (BPS, 2018). Kebonagung District has great potential for cocoa development in 2019. The total area of cocoa plantations is spread in almost all villages with a production level of 77 tons (BPS, 2020b). Cocoa is an attractive commodity for farmers. Research results (Irianto & Kartono, 2015), show that farmers tend to cultivate cocoa, because of demand and better price guarantees than other plantation commodities.

Soil is increasingly recognized as a non-renewable resource on a human life scale because once degraded is, regeneration is an extremely slow process. Given the importance of soils for crop and livestock production and for providing wider ecosystem services for local and global societies, maintaining the soil in good condition is vital. To manage the use of agricultural soils well, decision-makers need science-based, easy-to-apply, and cost-effective tools to assess changes in soil quality and function. Soil quality is the capacity of the soil to function in the ecosystem as land-use boundaries (Doran & Parkin, 1996). Soil quality indicators include physical, chemical, and biological properties of the soil that can describe soil conditions. According to Doran & Parkin (1996), soil quality indicators must show the processes of soil physics, soil biology chemistry in the ecosystem. Karlen et al. (Karlen et al., 2008), explained that the selection of soil quality indicators should describe the capacity to carry out its functions, namely (1) media for plant growth and biological activity, (2) regulators and dividers of water flow and storage in the environment, and (3) buffers. Environment from destruction by harmful compounds. Soil quality is a complex functional entity that cannot be measured directly, but by soil quality indicators. Therefore, selecting quantitative and qualitative indicators scientifically and reasonably is a challenge in formulating soil quality indexes (SQIs) (Chandel et al., 2018)a study was conducted to address the selection of most appropriate soil quality indicators and to know the status of soil quality in the area under different land uses. Principal component analysis (PCA.

Land-use type and agricultural management can be considered the major factors that affect soil quality due to the change it brings on the soil's physical, chemical, and, and soil biological properties. These changed properties, in turn, affect land productivity. The functions of soil are not only producing food and fibres, but also maintaining environmental quality, which improves the importance of the value of soil quality. Therefore, maintaining and improving soil quality is very important as it provides economic and environmental benefits. As improper land management can lead the harmful changes in soil function, there is a need for appropriate tools and methods to assess and monitor the soil quality (Supriyadi et al., 2021). Hence, the knowledge of soil quality is important for appropriate decision-making regarding sustainable soil management and land-use practices. Accordingly, assessing the soil quality status is imperative to design better soil management practices that enhance productivity and environmental sustainability. In addition, it helps planners and decision-makers evaluate, which land-use system is the most sustainable and take appropriate remedial measures considering the potentials. This study aims to assess soil quality in Kebonagung District for cocoa development.

Material and Methods

This research is an exploratory descriptive with a variable approach. The research was conducted through a field survey and supported by soil analysis results in the laboratory. The observed variables consisted of physical, chemical, and biological properties. The research was carried out with a field survey using a purposive sampling method (criteria determined by researchers), with 10 sample points three replications. At each site, soil samples were collected (0-100 cm depth) and mixed thoroughly, where there is one determining point, then we draw a diagonal line with a distance of 1 m, then composite. Analyses of soil physical and chemical properties were carried out on a composite sample from the selected soil layer. To analyze soil biological properties field, moist soil samples were taken in iceboxes, transported to the laboratory, and stored +4℃ till their analysis. Each Land Use is presented in Figure 1 and Table 1.

Soil analysis methods include physics, chemical, and biological indicators conducted in the laboratory by the method, such as soil texture by the piping method, bulk density was determined by the pycnometer method. Potential hydrogen was measured using a pH meter (Potentiometric). Total nitrogen was measured by the Kjeldahl method. Organic carbon (OC) was determined based on the Walkey Black rapid titration method. Cation Exchange Capacity (CEC), Base Saturation, and Available K were determined based on Ammonium Asetat 1 N extraction. Available P was measured with the Olsen method. Biomass carbon was determined by the fumigation method (Soil Reseacrh Institute, 2009). The

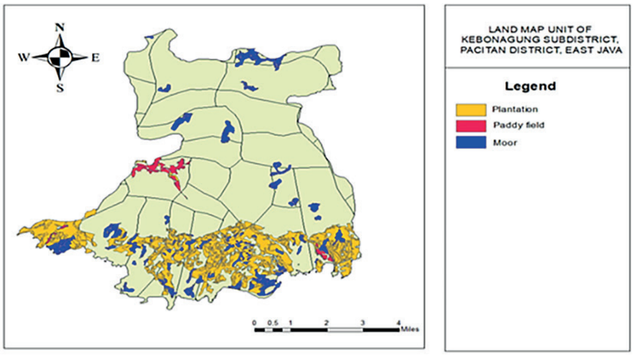

Fig. 1. Land map unit of Kebonagung subdistrict, Pacitan district, East Java

final result is Soil Quality Assesment. Soil quality assessment has three main stages referring to the method that has developed by Susan et al. (2001), first Minimum Data Set (MDS) selection, normalization of data, and integration of scoring results into soil quality index (SQI). Soil quality index is a method to assess the impact of land use and agricultural management on soil's physical, chemical, and biological properties. Soil quality index is a method of determining soil quality that is flexible and easier to use. Minimum Data Set Selection using the Minitab 18 application utilizing Principal Component Analysis (PCA). PCA aims to determine the indicators that have the most influence on soil quality and the most significant indicators seen with eigenvalues greater than 1; these indicators are used as the main components/Principal Components (PCs). Soil physical-chemical and biological characteristics measured with Principal Component Analysis where select Principal Components with eigenvalues >1 (Susan et al., 2001) and contribution to explaining variability 75%. For each PC selected, based on the criteria above, identify variables with highly weighted factor loadings. A multivariate procedure, such as Principal Component Analysis (PCA) and Loading Plot to get Minimum Data Set (MDS) (Jolliffe, 2012). That analysis to determine the most effective factors influence plot distribution, multivariate procedure. The selected data is then followed by Scoring (Si), based on (Chandel et al., 2018). Calculation of soil quality is done by summing the variable scores that have been multiplied by the Weight Index (Wi) Supriyadi et al. (2017) then classified according to (Cantú et al., 2007), shown by in (Table 2). the final PCA based MSQI equation is as follows:

$$MSQI \qquad \sum \frac{Wi \text{ x } Si}{n}$$

where:

SQI : Soil Quality Index;
Si : Scoring for selected indicator;
Wi : Weighting index for each selected indicator;
n : Number of variables.

Better soil quality and better performance of soil quality indicators indicate soil having a higher index score (Cantú et al., 2007).

Table 2. Soil Quality Classified

Soil Quality Index	Value	Class
Better	0.80-1	1
Good	0.60-0.79	2
Moderate	0.35-0.59	3
Low	0.20-0.34	4
Very Low	0-0.19	5

Results and Discussion

Tables 3 and 4 show the highest average pH is owned by secondary forest (6.32), rice field (6.2), upland (5.8), and secondary forest (5.75). Rice fields have the highest pH allegedly because they can control environmental conditions so that they have a generally close to neutral pH; this is following Harahap et al. (2021) which explains that paddy

Table 1. Land Map Unit Characteristic in Kebonagung District

LMU	Soil Types	Slope, %	Height, mdpl	Location	Land Use
1	Entisols	3-8	72	Karanganyar	Moor
2	Inceptisols	8-15	68	Karanganyar	Paddy Field
3	Inceptisols	0-3	8	Panjang	Paddy Field
4	Inceptisols	0-3	25	Karangnongko	Paddy Field
5	Inceptisols	3-8	10	Purwosari	Paddy Field
6	Inceptisols	0-3	175	Purwosari	Paddy Field
7	Entisols	3-8	89	Kebonagung	Secondary Forest
8	Inceptisols	8-15	118	Sidomulyo	Secondary Forest
9	Entisols	8-15	71	Banjar	Secondary Forest
10	Inceptisols	3-8	189	Karangnongko	Secondary Forest

Table 3. Soil Quality Indicator (pH, C-org, Total-N, Av-P, Av-K)

LMU	Land Use	pH	SOC, %	Total-N, %	Av-P, ppm	Av-K, cmol(+)/kg
1	Moor	5.8	0.28	0.31	0.27	0.11
2	Paddy Field	6	0.26	0.49	0.42	0.15
3	Secondary Forest	6	0.41	0.54	0.44	0.24
4	Secondary Forest	5.6	0.47	0.53	0.42	0.20
5	Paddy Field	6.2	0.35	0.32	0.28	0.16
6	Paddy Field	6.8	0.34	0.35	0.30	0.23
7	Secondary Forest	5.6	0.58	0.37	0.32	0.21
8	Paddy Field	6	0.28	0.32	0.27	0.22
9	Paddy Field	6	0.25	0.34	0.28	0.22
10	Secondary Forest	5.8	0.29	0.32	0.27	0.13

Table 4. Soil Quality Indicator (CEC, BS, BD, Porosity, MBC)

LMU	Land Use	CEC, cmol(+)/kg	KB, %	BD	Porosity	MBC
1	Moor	10.30	45.85	1.78	17.79	0.03
2	Paddy Field	10.87	54.69	1.73	20.59	0.02
3	Secondary Forest	16.84	47.80	1.29	41.79	0.03
4	Secondary Forest	24.77	39.24	1.23	44.57	0.03
5	Paddy Field	18.84	38.16	1.29	42.44	0.03
6	Paddy Field	16.41	54.69	0.81	55.24	0.03
7	Secondary Forest	19.48	43.23	1.43	35.35	0.05
8	Paddy Field	18.34	34.83	0.86	51.59	0.02
9	Paddy Field	17.00	25.32	0.96	33.69	0.02
10	Secondary Forest	15.55	26.11	0.84	62.65	0.02

fields have a pH that is easy to change, this is because rice fields generally have two conditions. that is flooded and not flooded, when inundated, the soil is reduced so that the pH rises and approaches neutral.

In contrast, when it is not flooded, the soil undergoes an oxidation process of Fe^{2+} and Fe^{3+}, causing the concentration of H+ to increase and lowering the pH to acid. pH is an indicator that is very influential on the availability of nutrients. The highest nutrient availability, is at neutral pH. At an acidic pH, some nutrients are not available, for example, at an acid pH, P, cannot be absorbed by plants, because it is fixed by Al, while at an alkaline pH, P, cannot be absorbed. Plants, because they were fixed by Ca (Gunawan et al., 2019). The CEC at the study site was low to moderate, which ranged from 10.30 cmol (+)/kg – 24.77 cmol (+)/kg. Hartati et al. (2013), explained that CEC in the soil greatly determines soil fertility, and plays a role in minimizing the potential for nutrient loss due to the leaching of nutrients, especially alkaline elements. The highest mean CEC was in secondary forest 19.09 cmol (+)/kg, in paddy fields 15.65 cmol (+)/kg and up to 10.3 cmol (+)/kg. The secondary forest has the highest CEC, because it has a better diversity of vegetation than rice fields and dry fields to reduce the rate of erosion. Hartatiet al. (2013), explained that the type of vegetation and vegetation density have a vital role in maintaining soil and reducing the rate of erosion. The high CEC is generally in line with base saturation. Still, the analysis results show that the highest base saturation is in upland 45.85%, while in paddy fields 42.38% and secondary forest 42.01%, this indicates that CEC at the research site is a potential CEC instead of a potential CEC. Actual CEC, Sahbudin et al. (2020), explained that CEC in tropical soils does not always describe the number of cations adsorbed on the soil, but only as CEC formed from a variable charge and did not describe the actual base cations adsorbed on the colloid surface.

Nitrogen (N) is an integral component that plays a role in forming proteins and amino acids. Nitrogen can be absorbed by plants in the form of ammonium ($NH^{4+)}$) and nitrite (NO^{2-} $^{).}$ Nitrogen in the soil is very easy to change from NH^{4+} to NO^{2-} this is because oxygen conditions in the rhizosphere affect the oxidation-reduction potential (Chunmei et al., 2020). The highest Total-N was in secondary forest land use 0.44%, rice fields 0.37%, upland 0.31%. The available P-value at the study site ranged from 0.27 ppm – 0.44 ppm, which is very low. The low P-available is thought to be due to land management factors; the average yield of P-available in dry fields is 0.27 ppm, rice fields are 0.31 ppm, and secondary forests are 0.36 ppm. George et al. (2018), explained that P in the soil could be sourced from inorganic P, and organic P. P availability is closely related to land use, fertilization, and organic matter. Potassium (K) is an essential macronutrient for plants. Potassium plays a role in metabolic processes and enzyme activation (Sukarjo, 2017). K in the soil has a dynamic form, namely: (1) K dissolved, (2) K can be exchanged, (3) K is not exchangeable, and (4) K mineral Cahyono & Minardi (2022). In all, LMU is included in the low category. The mean K available for each land use is as follows: rice field 0.2 cmol (+)/kg, secondary forest 0.18 cmol (+)/kg, upland 0.11 cmol (+)/kg. It is suspected that low K content in the soil is due to the leaching and transport of nutrients, without returning to the soil at harvest and the lack of K fertilization.

C-organic is an indicator that plays an important role in improving the soil's chemical, biological and physical properties; from the results of the analysis, C-organic ranges from 0.25% - 0.54%, which is in the very low category. C-organic in secondary forest 0.42%, rice field 0.28%, upland 0.28%. The secondary forest has the highest organic C, because the vegetation is more diverse. High organic C can be a buffer and improve soil physical properties, especially BD and soil porosity. Still, the analysis results of the average soil physical properties show that secondary forest has the highest BD 1.69 g/cm^3, rice fields 1.55 g/cm^3, and the moor is 1.34 g/cm^3. The secondary forest has the highest BD, compared to rice fields and dry fields, this causes the porosity of secondary forests to also below. The average analysis shows that the porosity of secondary forests is only 33.58 % the lowest compared to rice fields 38.24%, upland 47.33%, this indicates that under certain conditions the C-organic content cannot be a reference in determining the physical properties of soil in general.

The average MBC result shows that upland and plantations have a C-mic of 0.03 higher than that of Paddy Field 0.024, this is following Supriyadi et al. (2017)Indonesia's government has been promoting a program namely Merauke Integrated Food and Energy Estate (MIFEE that land with higher organic matter input will generally have a higher C-biomass of microbes. In addition, organic matter plays an important role in providing an energy source for microbes to trigger their growth and number. The soil correlation test aims to get the correlation of each soil quality indicator, the correlation test uses the Pearson correlation at the level of 5% (α = 0.05), the correlated indicator has a p-value of less than 0.05 and the Pearson correlation value (r) is close to 1 or -1. The correlation results are presented in Table 5.

The correlation between pH and available P is explained as the availability of P in the soil. Phosphorus (P), is the second essential nutrient after nitrogen, which has an important role in plant growth and development (Cahyono & Minardi, 2022). The availability of P in the soil is very low compared to the elements Nitrogen (N), calcium (Ca), and Potassium (K). At low pH, the availability of P is lower, because P in the soil is in a fixed form in the form of Al-P, Fe -P, Ca-P,

Table 5. Correlation of soil quality indicators

	pH	BD	Porosity	SOC	Av-P	Av-K	Total-N	BS	CEC
BD	-0.108								
	0.572								
Porosity	0.063	-0.568**							
	0.739	0.001							
C-org	-0.082	-0.194	0.285						
	0.666	0.305	0.127						
Av-P	**0.517****	0.288	-0.104	-0.211					
	0.003	0.122	**0.583***	0.264					
Av-K	**0.410***	-0.000	0.036	0.148	-0.071				
	0.025	1.000	0.850	0.434	0.708				
Total-N	0.272	**-0.431***	0.144	0.085	0.006	0.195			
	0.145	0.017	0.448	0.653	0.974	0.302			
BS	-0.129	-0.057	0.101	-0.043	-0.117	-0.004	0.245		
	0.498	0.766	0.595	0.822	0.540	0.984	0.192		
CEC	**0.368***	-0.056	-0.015	0.313	-0.083	**0.447***	0.196	-0.554	
	0.045	0.771	0.938	0.092	0.662	0.013	0.300	**0.001**	
MBC	-0.153	0.148	-0.305	-0.104	-0.228	-0.145	0.061	0.323	-0.217
	0.420	0.435	0.101	0.585	0.225	0.445	0.747	0.082	0.248

and P are bound (Minardi et al., 2016). The correlation of pH and available K is also explained as the availability of K nutrients in a certain pH range. pH is usually correlated with available K, and other alkaline cations explained Sahbudin et al. (2020) that the increase in pH is due to the decomposition process of various types of materials. Organic matter produces basic cations, such as Ca, Mg, K, and Na. The release of basic cations into the soil solution causes the soil to be saturated and ultimately increases the soil pH.

Negative correlation between BD and Porosity (r = -0.568), BD and Total-N (r = -0.431), Base Saturation and CEC (r = -0.554). Porosity is the ratio between macro and microspores and soil volume weight, soils with high BD have low porosity, which causes aeration, low water, and nutrient retention capabilities and provides more physical barriers to plant growth (Haridjaja et al., 2010). Porosity is strongly influenced by soil texture, clay textured soil has a higher porosity than sandy texture. This is because clay textured soils have more pores than sandy soils (Jayanti, 2015). In general, base saturation and CEC have a positive correlation. Still, under certain conditions, base saturation is not always positively correlated with CEC, high CEC is not always followed by an increase in soil KB. This happens, because CEC here is not an effective CEC, but a potential CEC is the number of cations, formed from a variable charge and does not describe the basic cations adsorbed on the colloidal surface (Sahbudin et al., 2020).

Determination of indicators with the highest sensitivity in soil quality assessment through Principal Component Analysis (PCA). Principle Component is a linear combination that is a variable as the maximum representation of the variance of the data set. The indicator selected as MDS must have an eigenvalue of 1 (Gewers et al., 2018). PCA results are presented in Table 6.

Table 6. Minimum Data Sets

Eigenvalue	2.3839	1.9814	1.4988	1.3179
Proportion	0.238	0.198	0.150	0.132
Cumulative	0.238	0.437	0.586	0.718
Variable	PC1	PC2	PC3	PC4
pH	0.387	-0.294	-0.444	0.004
BD	-0.307	-0.480	0.094	0.185
Porosity	0.283	0.410	-0.016	-0.425
C Organik	0.268	0.241	0.348	0.111
Av-P	0.044	-0.436	-0.413	-0.369
Av-K	0.376	-0.106	-0.079	0.419
Total-N	0.283	0.244	-0.437	0.249
KB	-0.230	0.370	-0.453	0.158
CEC	0.474	-0.211	0.276	0.299
MBC	-0.320	0.121	-0.153	0.534

Based on the results of PCA analysis for Kebonagung District, 6 indicators from 4 PCs were found as the main components. On PC 1, the pH, K-Available, and CEC indicators were selected. pH is correlated with available K and CEC. PC 1, represents 23.8% of data for soil quality index analysis. In PC 2, only one indicator was selected, namely porosity. Porosity was chosen, because it had the highest weight value. PC 2 represented 19.8% of the data for assessing the soil quality index. PC 3 and PC 4 selected only one independent indicator, namely organic C for PC 3, and C-microbial biomass for PC 4. PC 3 and PC 4, represented 15% and 13.2%, respectively, for soil quality index analysis. PC analysis will produce the Minimum Data Set (MDS) for soil quality, which is the smallest data set to represent all the values of the soil quality indicators used. The indicator selected as MDS is used to determine the SQI by calculating the weighted index value (Wi), where the Wi value is obtained through the division between proportion and cumulative (Table 5). The selected MDS were then weighted by index weighting through cumulative proportions. The results of the index weighting are presented in Table 7.

Table 7. Weighting index

No	MDS	Proportion	Cummulative	Wi
1	pH	0.46	0.80	0.29
2	SOC	0.46	0.80	0.29
3	Total-N	0.46	0.80	0.29
4	MBC	0.46	0.80	0.29
5	Porosity	0.19	0.80	0.24
6	Av-P	0.15	0.80	0.18

Scoring is done by matching data from laboratory analysis (1). The higher the score indicator value, the better the land, or the better it carries out its functions (Supriyadi et al., 2021). The next assessment of the soil quality index is the multiplication of the weighting index with the scoring indicator. The results of the SQI assessment are presented in Table 8. Based on Table 8, it is known that the soil quality index in Kebonagung District ranges from 0.31 to 0.41, which belongs to the low to medium class. Each land use has a different quality, the assessment of soil quality for each type of land use is presented in Figure 2.

From Figure 2, it is known that the use of moor has a soil quality index of 0.32, which is included in the low class, 0.40 for rice fields included in the medium class, and 0.39 secondary forest, which is also included in the medium class. Regarding the strategic plan for cocoa development in Kebonagung District, it is necessary to analyze the limiting factors of soil quality as a reference for recommendations for improvement to support cocoa productivity. Several indi-

Table 8. Scoring Soil Quality Index

No	MDS	Si									
		1	2	3	4	5	6	7	8	9	10
1	pH	2	2	2	2	3	5	3	2	3	2
2	SOC	3	2	2	3	3	3	3	3	2	3
3	Total-N	2	2	3	2	2	3	2	3	2	2
4	MBC	1	1	1	1	1	1	1	1	1	1
5	Porosity	4	5	5	5	5	5	5	5	5	5
6	Av-P	1	1	1	1	1	1	1	1	1	1
	SQI	0.34	0.36	0.41	0.41	0.39	0.41	0.40	0.41	0.41	0.30

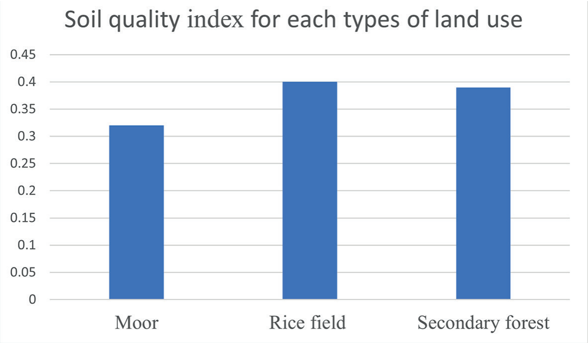

Fig. 2. Soil quality index for each types of land use

cators need improvement from the research results through fertilization of primary macronutrients, soil improvement materials, or using soil processing.

The correlation between SQI and soil quality indicators shows that the parameters that are the determining factors that support the increase in SQI, namely pH, CEC, and available K, soil management is based on indicators that correlate. Soil quality indicators correlated with SQI are presented in Table 9.

Based on the results obtained from the correlation test between SQI and soil quality indicators, it can be seen that the recommended parameters for improvement efforts are pH, CEC, and available K. Recommendations for improvement of pH can be made by giving dolomite. The provision of Dolomite can be used to increase the availability of exchangeable base cations, especially Ca and Mg in the soil solution so that it is expected to be able to reduce the concentration of H+ in the soil solution and increase the pH. Basuki & Sari (2020) added that the administration of dolomite increased the pH by 24.6%. This result is in accordance with the results of a study conducted by Basuki & Sari (2019), which reported that the use of dolomite had a significant effect on increasing soil pH, because dolomite contains 30, 17% CaO and 16.59% MgO. Provision of cocoa husk compost can be an appropriate alternative recommendation effort considering the abundant availability of cocoa husks and the benefits it provides, such as improving the physical, chemical and biological properties of soil, Minarsih et al. (2013), further research results.

Didiek & Away (2004), proved that the cocoa pod compost had a pH of 5.4, Total-N 1.30%, C-organic 33.71%, P_2O_5 0.186%, K_2O 5.5%, CaO 0.23%; and 0.59% MgO. The nutrient content of cocoa husk compost other than organic C is relatively low, but the addition of cocoa husk compost has been shown to increase the soil C/N ratio and soil pH. The reshuffle of organic matter results will produce basic cations, such as Ca, Mg, K, and Na, increasing the pH. An increase in pH due to the addition of organic matter, will cause saturated base cations in the soil, so that the KB value will also increase in line with the availability of P (Sugiyanto et al., 2008). Improvement of K nutrient content is carried out through balanced fertilization. Recommendations for balanced fertilization are based on references from (Ritung et al., 2011). Real conditions and nutrient requirements are presented in kg/ha, making it easier to provide fertilizer recommendations. real conditions of nutrients in Bandar District are presented in Table 10.

Table 9. Correlation of soil quality indicators

No	Indicator	Correlation
1	pH	0.633**
2	BD	-0.090
3	Porosity	0.016
4	MBC	0.011
5	SOC	0.233
6	Av-P	0.069
7	Total-N	0.217
8	CEC	0.526**
9	Av-K	0.610**
10	BS	0.010

Conclusion

In each land use, there are differences in soil quality class, moor has a low-quality class (0.32), while rice fields (0.40) and secondary forest (0.39), have a medium class. The indi-

Table 10. Real conditions, nutrient deficiency and fertilizer recommendations for K

LMU	Real condition, kg ha^{-1}	Nutrient deficiency, kg ha^{-1}	KCL fertilizer, kg ha^{-1}
1	8.30	40.7	88.61
2	15.09	42.0	91.40
3	12.52	23.5	51.14
4	16.74	36.97	80.37
5	12.86	53.30	115.88
6	11.76	35.38	76.91
7	12.80	39.13	85.07
8	9.66	32.97	71.69
9	10.13	32.54	70.74
10	12.8	57.72	125.48

cators that become the limiting factor of soil quality based on the correlation test results are pH, CEC, and K-Available. Based on the limiting factors obtained, recommendations for improvement are by giving dolomite and captain, cocoa husk compost, and KCL balanced fertilization.

References

Basuki, & Sari, K. V. (2019). The Effectiveness of Dolomite in Maintaining Inceptisol Soil pH of Blimbing Sugarcane Plantation in Djatiroto. *Buletin Tanaman Tembakau, Serat Dan Minyak*, *11*(2), 58–64. https://doi.org/10.21082/btsm.v11n2.2019.58.

BPS (2018). Indonesian Cacao Statistik. BPS-Statistic Indonesia.

BPS (2020a). *Indonesians Cocoa Statistic.* BPS-Statistic Indonesia.

BPS (2020b). Kebonagung Subdistrict in Statistic. BPS-Statistic Indonesia.

Cahyono, O. & Minardi, S. (2022). Effect of Fast Dissolved Phosphorus Fertilizer on the Growth, Seed Product, and Phosporus Uptake Efficiency of Soybean. *Agrivita*, *44*(1), 21–30.

Cantú, M. P., Becker, A., Bedano, J. C. & Schiavo, H. F. (2007). Soil quality evaluation using indicators and indices. *Ciencia Del Suelo*, *25*(2).

Chandel, S., Hadda, M. S. & Mahal, A. K. (2018). Soil Quality Assessment Through Minimum Data Set Under Different Land Uses of Submontane Punjab. *Communications in Soil Science and Plant Analysis*, *49*(6), 658–674. https://doi.org/10.1080/00103624.2018.1425424.

Chunmei, X. U., Liping, C. H. E. N., Song, C. H. E. N., Guang, C. H. U., Danying, W. A. N. G. & Xiufu, Z. H. (2020). Science Direct Rhizosphere Aeration Improves Nitrogen Transformation in Soil and Nitrogen Absorption and Accumulation in Rice Plants. *Rice Science*, *27*(2), 162–174. https://doi.org/10.1016/j.rsci.2020.01.007.

Doran, J. W. & Parkin, T. B. (1996). Quantitative Indicators of Soil Quality: A Minimum Data Set. Soil Science Society of America, Madison, *49*, 25–37.

Gewers, F., Ferreira, G. R., Arruda, H. F. De & Silva, F. N. (2018). Principal Component Analysis: A Natural Approach to Data Exploration. *Research Gate*, *54*(4),1-34.

Haridjaja, O., Hidayat, Y. & Maryamah, L. S. (2010). Effect Of Soil Bulk Density On Soil Physical Properties And Seed Germinations Of Peanut And Soybean. *Jurnal Ilmu Pertanian Indonesaia*, *15*(3), 147–152.

Hartati, S., Minardi, S. & Ariyanto, D. P. (2013). Zero Point of Charge of Various Organic Fertilizer : The Effect on Soil Cation Exchange Capacity in Degraded Lands. *Sains Tanah*, *10*(1979), 27–36.

Irianto, B. & Kartono, G. (2015). Farming assessment of cocoa-based plantation commodities in Pacitan District, East Java. *Balai Pengakjian Teknologi Pertanian Jawa TImur*, 445–459.

Jayanti, K. D. (2015). Relationship between levels of sand fraction, clay fraction, organic matter and volume weight to available water content in rice field soils in Poso district., *12.*

Jolliffe, I. T. (2012). Principal Component Analysis. *Second Edition* (2nd ed.). *Springer,* London*,* 1.

Karlen, D. L., Andrews, S. S., Wienhold, B. J. & Zobeck, T. M. (2008). Soil Quality Assessment: Past, Present and Future. *J. Integr. Biosci.*, *6*(1), 3–14.

Minarsih, M., Arif, S., Rini, M. V. & Rusdi, E. (2013). Effect of Cocoa Fruit Peel Compost as a Mixture of Seedling Media and NPK Fertilizer (15:15:15) Growth of Cocoa Seedlings. *Journal Agrotek Tropika*, *1*(2), 189.

Ritung, S., Nugroho, K., Mulyani, A. & Suryani, E. (2011). Technical Guidelines for Land Evaluation for Agricultural Commodities. *Balai Besar Peneltiian dan Pengembangan Sumberdaya Lahan Pertanian*. Jakarta, 1.

Sahbudin, S., Khairullah, K. & Sufardi, S. (2020). Soil Acidity and Cation Exchange Properties of Mollisols and Ultisols in Drylands of Aceh Besar District. *Jurnal Ilmiah Mahasiswa Pertanian*, *5*(3), 25–34. https://doi.org/10.17969/jimfp.v5i3.15407.

Soil Reseacrh Institute (2009). Technical Instruction For Chemical Analysis of Soil, Water and Plants. *Balai Penelitian Tanah*, Jakarta, 1.

Sugiyanto, Baon, J. B. & Wijaya, A. (2008). Chemical Properties and Nutrient Uptake of Cocoa as Affected by Application of Different Organic Matters and Phosphate Fertilizers. *Pelita Perkebunan*, *24*(90), 188–204.

Supriyadi, S., Purwanto, P., Sarijan, A., Mekiuw, Y., Ustiatik, R. & Prahesti, R. R. (2017). The assessment of soil quality at paddy fields in Merauke, Indonesia. *Bulg. J. Agric. Sci.*, *23*(3), 443–448.

Supriyadi, S., Vera, I. L. P. & Purwanto, P. (2021). Soil Quality at Rice Fields with Organic, Semi-organic and Inorganic Management in Wonogiri Regency, Indonesia. *Caraka Tani: Journal of Sustainable Agriculture*, *36*(2), 259. https://doi.org/10.20961/carakatani.v36i2.42556.

Susan, S. A. & Carrols, R. S. (2001). Designing A Soil Quality Assesment Tool For Sustainable Agriculture. *Ecological Application*, *11*(6)*,* 1573–1585.

UNIED (2019). Indonesia Exibank Institute. Export Projections by Industry: Leading Commodities. *Indonesia Exibank Institute*. Jakarta,1.

*Received:***June, 05, 2022**; *Accepted:***October,10, 2022**; *Published:* **August, 2023**