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STATUS KESUBURAN DAN KUALITAS TANAH UNTUK PENGELOLAAN LAHAN SAWAH BERBASIS PEMUPUKAN BERIMBANG DI KECAMATAN MENDOYO

SOIL FERTILITY AND QUALITY STATUS FOR BALANCED FERTILIZATION-BASED AGRICULTURAL LAND MANAGEMENT IN MENDOYO DISTRICT

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ABSTRACT

Soil fertility and quality have declined due to conventional farming practices that neglect fertilization. To restore soil fertility and quality, an evaluation is being conducted to determine balanced fertilization doses. This research aims to identify the soil fertility and quality status in the Mendoyo Subdistrict so as to provide recommendations for balanced fertilization in specific agricultural areas. The methods used were surveying and laboratory soil testing. The results demonstrated that the Mendoyo Subdistrict exhibited a combination of moderate and high soil fertility levels. The soils with moderate status were located in HLU (Homogeneous Land Units) I, II, V, VIII, IX, and X, while the those with high ones were located in HLU III, IV, VI, and VII. Moreover, the subdistrict exhibited varying levels of soil quality, ranging from poor to moderate, good, and very good. The poor-quality soil was located in HLU I, the good ones were located in HLU II, III, and IV, and the very good ones were located in HLU V, VI, VII, VIII, IX, X. The limiting factors in this research included texture, C-organic, nutrients (N, P, and K), and C-biomass. Meanwhile, the advanced regression and correlation tests indicated that C-organic was the most influential factor in determining soil fertility and quality, thus resulting in a recommended organic fertilizer dose of 2 t ha^{-1} for rice (Oryza sativa L), 15 kg plant^{-1} th^{-1} for cocoa (Theobroma cacao L) and robusta coffe (Caffea canephora), and 10 t ha^{-1} for coconut (Cocos nucifera) and banana (Musa paradisiaca L). Inorganic fertilizer doses vary depending on the soil's N, P, and K content.

ABSTRAK

Status kesuburan dan kualitas tanah pada lahan pertanian di Kecamatan Mendoyo tegolong menurun karena praktek pertanian konvensional dan pengelolaan lahan yang tidak optimal, oleh karena itu perlunya pemupukan berimbang spesifik lokasi untuk mengembalikan kesuburan tanah dan kualitas tanah. Penelitian bertujuan untuk mengetahui status kesuburan dan kualitas tanah di Kecamatan Mendoyo sebagai acuan pembuatan rekomendasi pemupukan berimbang spesifik lokasi pada lahan pertanian. Metode yang digunakan dalam penelitian ini adalah metode survei dan uji tanah di laboratorium. Hasil penelitian menunjukkan di Kecamatan Mendoyo memiliki dua status kesuburan tanah yaitu status kesuburan sedang berlokasi di SLH I, II, V, VIII, IX, X, status kesuburan tinggi berlokasi di SLH III, IV, VI, VII. Hasil penelitian kualitas tanah terdapat tiga kriteria yaitu buruk berlokasi di SLH I, kriteria baik berlokasi di SLH II, III, IV, dan kriteria sangat baik berlokasi di SLH V, VI, VII, VIII, IX, X. Faktor pembatas dalam penelitian ini adalah tekstur, C-organik, unsur hara (N, P dan K) dan C-biomassa. Hasil uji lanjut regresi dan korelasi didapatkan faktor C-organik merupakan faktor yang paling berpengaruh dalam kesuburan dan kualitas tanah, dengan demikian dosis pupuk organik adalah 2 t ha^{-1} untuk padi (*Oryza sativa* L), 15 kg pohon^{-1} th^{-1} untuk coklat (*Theobroma cacao* L) dan kopi robusta (*Caffea canephora*), 10 t ha^{-1} untuk kelapa (*Cocos nucifera*) dan pisang (*Musa paradisiaca* L). Dosis pupuk anorganik bervariasi tergantung pada kadar N,P dan K tanah.

KATA KUNCI:
Evaluasi tanah, lahan perkebunan, lahan sawah, pemupukan berimbang

1. INTRODUCTION

Jembrana, a regency situated in Bali, plays a vital role in the regional economy by contributing significantly to the agricultural sector. One of its subdistricts, Mendoyo, has the largest agricultural sector among the other subdistricts. It has the highest rice production in the regency and also shows great potential for producing plantation corps. In 2020, it produced 237.63 tons of rice (*Oryza sativa* L), 10,766 kg of banana (*Musa paradisiaca* L), 6,943.07 tons of coconut (*Cocos nucifera*), 1,135.09 tons of cacao (*Theobroma cacao* L), and 177.40 tons of robusta coffee (*Caffea canephora*) (BPS Jembrana Regency, 2021)(The Government of Jembrana Regency, 2023).

So as to maintain the productivity of rice plants and plantation corps, as well as to boost yields and prevent fluctuations, it is of importance to provide regular management and fertilization in Mendoyo. According to the scientific data from the Government of Jembrana Regency in 2022, the rice production fluctuated from 2018 to 2022, with the following quantities: 22,243.40 tons, 22,777.85 tons, 237.63 tons, 20,387.45 tons, and 19,068,40 tons respectively (BPS Bali. 2022). In addition, there was a decline in cacao production from 7,008.35 tons to 6,943.07 tons, and a fall in robusta coffee production from 178.42 tons to 167.40 tons between 2019 and 2020 (BPS Jembrana Regency, 2021). The fluctuating rice production and the declining plantation crop yields in Mendoyo indicate a decline in soil fertilization and quality.

One factor contributing to the decrease in soil fertility and quality is the inadequacy of land management practices, including fertilization. Failure to evaluate the dosage, method, and type of fertilizer when aiming to enhance productivity potentially leads to the loss of ecosystems and reduced soil fertility and quality (Ganti *et al*., 2023). Moreover, the need for more information regarding soil fertility and quality is the cause of inadequate production. The evaluation of soil fertility status aims to identify the soil's condition, acidity (pH), nutrient availability, and cation exchange capacity (CEC). It also holds great importance as it assesses physical, chemical, and biological factors of soil that affect the growth of plants. The information on soil condition is crucial for it determines the growth of plants through the soil types and its chemical, biological, and physical properties (Gratzfeld, 2016).

Balanced fertilization for specific areas is the key factor to increase soil fertility and quality. It aims to provide plants with essential nutrients while preventing excessive fertilization that is detrimental to the environment (Sanchez, 2019). According to Adi et al., (2019), the optimal doses for upland rice are 120.60 kg.ha^{-1} of N, 32.67 kg.ha^{-1} of P_2O_2, and 46,28 kg.ha^{-1}; those for coffee plants are 265 kg.ha^{-1} of Urea, 135 kg.ha^{-1} of SP-36 and 185 kg.ha^{-1}. Cacao plants require 200 kg.ha^{-1} of Urea, 200 kg.ha^{-1} of SP-36, and 150 kg.ha^{-1} of KCl; and coconut plants grow with 125 kg.ha^{-1} of Urea, 95 kg.ha^{-1} of SP-36, and 185 kg.ha^{-1} of KCl (Indonesian Soil Research Institute, 2021). The recommended fertilization is deemed impracticable due to the variety of soil fertility and quality across different regions. Effective fertilization is among the significant aspects of modern farming to ensure adequate and high-quality crop production while also preserving environmental sustainability (Juarti, 2016).

The evaluation can provide supporting data on soil fertility and quality that are valuable for improving the efficacy of fertilizer application, mitigating the risk of environmental pollution due to excessive fertilization, and increasing crop productivity and quality.

2. MATERIALS AND METHOD

2.1 Description of the Research Area

This research was conducted in the Mendoyo Subdistrict, Jembrana Regency, which is directly adjacent to the western side of Jembrana, the eastern side of the Pekutatan Subdistrict, and the northern side of the Buleleng Regency. Figure 1 displays the map of the research area. The analysis of several variables was conducted at the Soil and Environment Laboratory, Faculty of Agriculture, Universitas Udayana.

2.2 Data Collection

The data collected in this research consisted of both primary and secondary sources. The primary data comprised the field observation results and laboratory results, including the physical properties of soil (texture, porosity, bulk density (BD), and field capacity water content (FC)), chemical properties of soil (C-organic, total N, P & K availability, total P & K, CEC, and Base Saturation (BS)), and biological property of soil (C-biomass). The secondary ones comprised the administrative map of Mendoyo Subdistrict, a soil map at a scale of 1:25,000, a Digital Elevation Model (DEM) at a scale of 1:25,000, a land use map at a scale of 1:25,000, and analysis guidelines of physical, chemical, and biological properties of soil Indonesian Soil Research Institute 2nd edition.

2.3 Map of Homogeneous Land

The procedure of mapping the homogeneous land units involved processing the digital data and overlaying the administrative map of the Mendoyo Subdistrict with a soil map, a land use map, and a DEM; all were at a scale of 1:25,000. Consequently, there were ten sample locations categorized as HLU (Homogeneous Land Units) with criteria ranging from 1 to 5 for rice fields, and HLU ranging from 6 to 10 for mixed plantation fields (Figure 2).

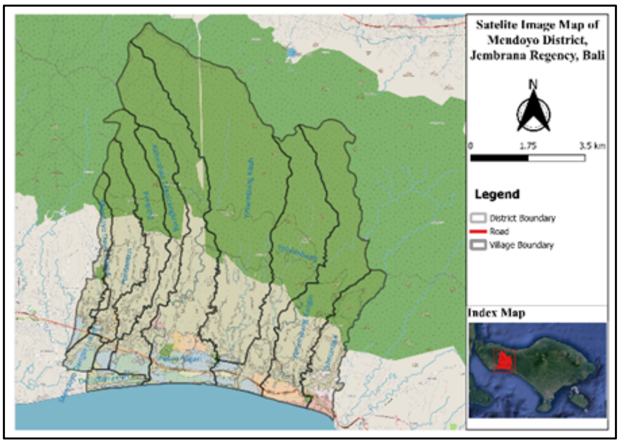


Figure 1. Research Area

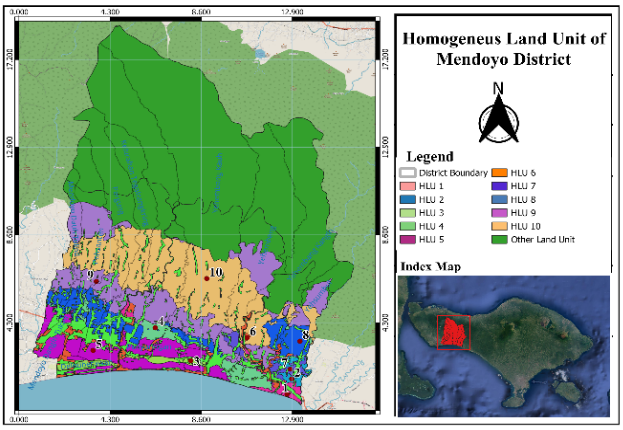


Figure 2. Map of Homogeneous Land Units

2.4 Soil Sampling and Laboratory Analysis

The researchers obtained soil samples through purposive sampling, specifically selecting sample points indicated by each HLU. At each location point, five soil samples were extracted and composited. The composites were used as specimens for certain soil characteristics.

The samples comprised both intact and disturbed soils. An intact soil sample was obtained from the subsurface at a depth of 0-30 cm, maintaining its original form as closely as possible. A soil ring sampler was used to extract soil samples and measure their volumetric weight and porosity. Disturbed soil refers to a soil sample extracted from subsurface at a depth of 0-30 cm and weights 1kg. It was obtained using tools a hoe and earth augher. The sample was used to determine the FC, soil texture, N, P, K, CEC, BS, C-organic, and C-biomass. Moreover, soil fertility and quality analysis comprised the physical, chemical, and biological properties of soil. It was conducted using the standardized method for parameter measurement.

2.5 Scoring of Soil Fertility Criteria and Soil Quality Index

The soil analysis was conducted to determine the assessment of soil fertility and quality status. The status was measured by comparing analysis results of soil fertility indices, including C-organic, total P and K, CEC, and BS based on the PPT method (1995). In addition, the soil quality index was obtained by classifying the constraining factor and assigning a relative weight to each soil quality indicator, as outlined by Lal (1994). The constraining factor was scored based on the absence of extreme height, using a scale ranging from 1 to 5. Below is the formula for calculating the Soil Quality Index (SQI).

$$SQI = PP + CP + BP \quad (1)$$

Notes : SQI stands for Soil Quality Index. P.P. Stands for soil's physical property, C.P. for soil's chemical property, and B.P. for soil's biological property.

According to Lal (1994), the result of the SQI calculation is compared with the soil quality criteria.

2.6 Balanced Fertilization Specific Area

The instruction and recommended dose of balanced fertilization for specific areas were formulated based on the results of soil fertility status, soil quality, and adjustment to the Regulation of Minister of Agriculture Number 40 of 2007 on Rice Field. Meanwhile, the plantation field was adjusted to the Indonesian Soil Research Institute in 2021.

2.7 Data Analysis

The soil fertility and quality status were evaluated using the data obtained from laboratory soil analysis. The soil fertility analysis was matched using the fertility status criteria based on the PPT criteria (1995). The soil quality standards were determined by assigning a relative weights to the soil quality indicators and calculating the Soil Quality Index (SQI) based on Lal's criteria (1994). Additionally, correlation analysis was used to identify the direction and relation of each parameter of soil fertility and quality. Subsequently, regression analysis was used to ascertain the dependency of each parameter on soil fertility and quality.

3. RESULT AND DISCUSSION

3.1 Land Use in Mendoyo Subdistrict

The research area covered a total of 29,449 hectares of land located in Mendoyo Subdistrict, Jembrana Regency. The area consisted of 2,505.57 hectares dedicated to rice cultivation and 8,064.74 hectares were used to cultivate banana, coconut, cacao, and robusta coffee plants. The rest of the area, 18,878.69 hectares, covered the non-agricultural landscape, including roads, settlements, offices, rivers, and forests.

3.2 Soil Fertility

As measured by the criteria adjustment of soil fertility status (PPT, 1995), the soil in the Mendoyo Subdistrict has moderate and high soil fertility status. The soils with moderate status were located in HLU I, II, V, VIII, IX, and X, while the high-status ones were located in HLU III, IV, VI, and VII, as indicated in 3. The soils were fertile due to a lack of land management. Intensive and long-term land management will reduce soil fertility (Soekamto et al., 2023). Additionally, the absence of input and organic matter in soil might reduce its fertility. Organic soil matters play a crucial role in soil fertility as they contain essential nutrients and have the ability to restore soil properties (Kamsurya and Botanri, 2022).

The primary determinant (constraining factor) of the soil fertility status is the C-organic. The results of the analysis of soil C-organic showed a range of content from very low to moderate. The low level of C-organic was due to inadequate input and the reintegration of the residual harvest into the soil. The addition of compost or organic matter into the soil will increase the C-organic content (Syachroni, 2019). Nathan et al., (2023) reported that the addition of organic matters combined with inorganic fertilizers such as NPK, SP-36, and KCl at doses of 0.43g, 0.19g, and 0.11g respectively resulted in alteration of C-organic content compared to the pre-treatment analysis results.

Organic matter is a significant reservoir of C-organic that is essential for soil fertility. It functions as a nutrient-release solvent and as soil nutrients such as P and K (Kusumawati, 2021a). Additionally, this research has found a positive association between the intake of this substance and increased levels of P and K, as determined using regression testing. The test results showed a notable increase in the soil's total K content due to the favorable effect of C-organic, as seen by the values of 0.843 and 0.710 (Figure 3).

Table 1. Analysis result of soil fertility parameter

HLU	CEC (me $100g^{-1}$)	BS (%)	Total P (ppm)	Total K (me $100g^{-1}$)	C-organic (%)
I	33.960 H	69.330 H	1483.904VH	49.937 H	0.440 VL
II	28.740 H	94.490VH	1.908.929VH	51.227 H	1.730 L
III	31.290 H	94.820VH	2.152.766VH	54.419 H	2.210 M
IV	33.000 H	72.460VH	1.227.628VH	56.608 H	2.330 M
V	45.130 H	86.320VH	1.076.155VH	48.399 H	1.360 L
VI	24.370 H	90.910VH	1.640.513VH	51.864 H	2.310 M
VII	28.690 H	100.00VH	2.143.958VH	59.684 H	3.730 H
VIII	31.680 H	89.860VH	4.840 VL	49.885 H	1.480 L
IX	33.260 H	78.870VH	478.970 VH	52.419 H	1.120 L

Note: VH = Very High; H = High; M = Moderate; L = Low; VL = Very Low.

Table 2. Soil Fertility status in Mendoyo Subdistrict

HLU	CEC	BS	P, K, C-organic	Fertility Status
I	H	H	≥ 2 H with L	Moderate
II	H	H	≥ 2 H with L	Moderate
III	H	H	≥ 2 H without L	High
IV	H	H	≥ 2 H without L	High
V	H	H	≥ 2 H with L	Moderate
VI	H	H	≥ 2 H without L	High
VII	H	H	≥ 2 H without L	High
VIII	H	H	≥ 2 H with L	Moderate
IX	H	H	≥ 2 H with L	Moderate
X	H	H	≥ 2 H with L	Moderate

Note: H = high; L = Low.

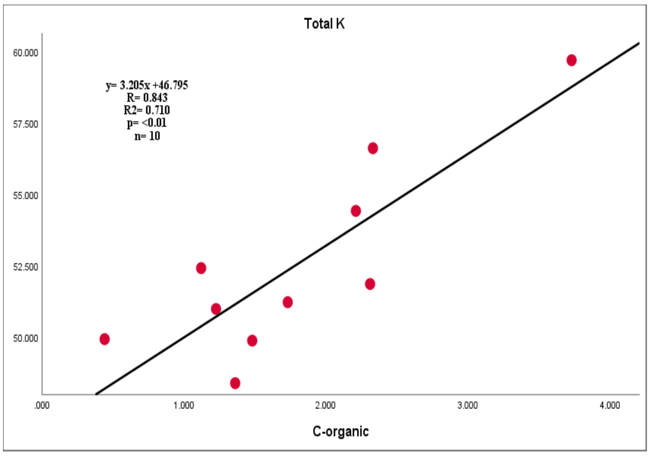


Figure 3. Correlation and Regression of C-organic and Total K

The correlation and regression analysis also demonstrated a negligible positive association between C-organic contents and the soil's total P. This result showed that the inclusion of organic matter increases total K and total P contents. (Ariyanti *et al.*, 2023) stated that the addition of 100 g of empty palm tree bunches and 160 g of palm tree stalks can effectively preserve and increase the soil's total K, while simply maintaining the soil's total P.

3.3 Soil Quality

The soil quality was assessed using a set of 10 Minimum Data Set (MDS) criteria, including the physical properties of soil, chemical properties of soil and biological property of soil. The analysis of the soil's physical properties, chemical properties, and biological properties was adjusted to the constraining factor and relative weighting, as outlined by (Lal, 1994). The data analysis results are presented in Table 3, Table 4, and Table 5.

Meanwhile, the soil quality criteria were calculated by summing the weights of physical, chemical, and biological properties. Based on the calculation, the subdistrict exhibited varying levels of soil quality, ranging from poor to moderate, good, and very good. The area with poor-quality soil was located in HLU I, covering 183,58 hectares. Conversely, those with good-quality ones were located in HLU II, III, and IV, spanning a total area of 2.321,99 hectares. The areas with very good-quality soil were located in HLU V, VI, VII, VIII, IX, X, covering a substantial 8.064,75 hectares.

Table 3. Analysis Results of the Parameter of Soil's Physical Property

HLU	Soil Texture	BD (g cm^{-3})	Porosity (%)	FC (%)	Total Weight
I	Clay (5)	1.747 (5)	17.210 (3)	41.320 (1)	14
II	Clay (5)	0.925 (1)	45.588 (1)	39.270 (1)	8
III	Clay (5)	0.990 (1)	37.063 (1)	41.650 (1)	8
IV	Loam (1)	1.441 (4)	10.902 (4)	47.900 (1)	10
V	Silt clay loam (2)	1.280 (2)	20.761 (1)	47.680 (1)	6
VI	Sand clay loam (3)	1.051 (1)	39.493 (1)	40.650 (1)	6
VII	Sandy clay (5)	0.965 (1)	38.457 (1)	46.380 (1)	8
VIII	Sandy loam (3)	1.001 (1)	43.984 (1)	41.270 (1)	6
IX	Sandy clay loam (3)	1.062 (1)	42.062 (1)	43.750 (1)	6
X	Sandy clay loam (3)	1.070 (1)	36.611 (1)	37.960 (1)	6

Note: 1 = without any limitations; 2 = Mild limiting factor; 3 = Moderate limiting factor; 4 = Severe limiting factor; 5 = Extreme limiting factor.

Table 4. Analysis Results of the Parameter of Soil's Chemical Property

HLU	C-organic(%)	Soil pH	CEC (me 100g^{-1})	BS (%)	Nutrients			Average Nutrient	Total Weight
					Total N (%)	Available P (ppm)	Available K (ppm)		
I	0.440 (5)	6.60 (1)	33.960 (2)	69.330 (2)	0.060 (5)	2.490 (5)	117.050 (1)	3.6	13.6
II	1.730 (3)	6.60 (1)	28.740 (2)	94.490 (1)	0.060 (5)	12.000 (4)	198.210 (1)	3.3	10.3
III	2.210 (3)	6.50 (1)	31.290 (2)	94.820 (1)	0.060 (5)	21.620 (3)	223.200 (1)	3	10
IV	2.330 (3)	6.60 (1)	33.00 (2)	72.460 (1)	0.040 (5)	16.870 (3)	231.700 (1)	3	10
V	1.360 (3)	6.60 (1)	45.130 (1)	86.320 (1)	0.220 (3)	9.800 (5)	133.140 (1)	3	9
VI	2.310 (3)	6.70 (1)	24.370 (3)	90.910 (1)	0.100 (4)	21.440 (3)	228.700 (1)	2.6	10.6
VII	3.730 (2)	6.50 (1)	28.690 (2)	100.00 (1)	0.140 (4)	62.480 (1)	300.840 (1)	2	8
VIII	1.480 (3)	6.70 (1)	31.680 (2)	89.860 (1)	0.100 (4)	1.720 (5)	152.520 (1)	3.3	10.3
IX	1.120 (3)	6.60 (1)	33.260 (2)	78.870 (1)	0.110 (4)	4.220 (5)	168.760 (1)	3.3	10.3
X	1.225 (3)	6.70 (1)	33.160 (2)	92.310 (1)	0.110 (4)	3.360 (5)	155.120 (1)	3.3	10.3

Note: 1 = without any limitations; 2 = Mild limiting factor; 3 = Moderate limiting factor; 4 = Severe limiting factor; 5 = Extreme limiting factor.

Table 5. Analysis results of the parameter of soil's biological property

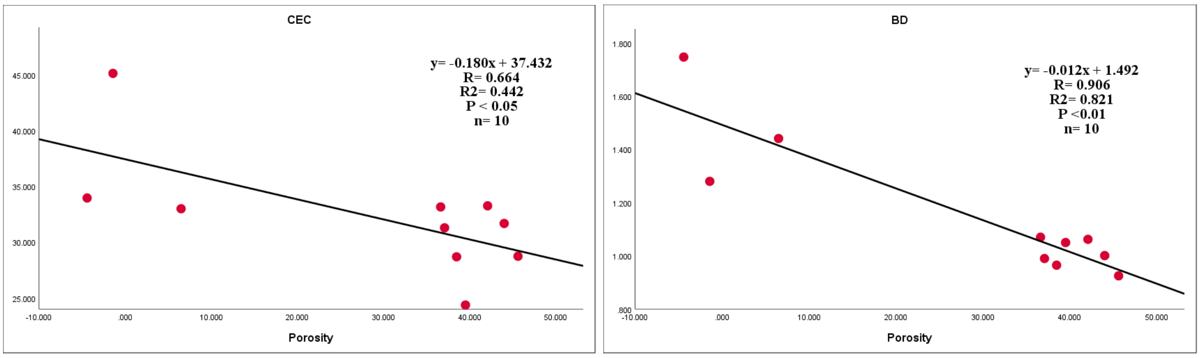
HLU	C-biomass (mg CO_2 kg^{-1})	Total Weight
I	10,096(3)	3
II	10,664(3)	3
III	7,944(4)	4
IV	11,531(3)	3
V	13,533(3)	3
VI	11,531(3)	3
VII	12,382(3)	3
VIII	12,949(3)	3
IX	12,382(3)	3
X	12,666(3)	3

Note: 1 = without any limitations; 2 = Mild limiting factor; 3 = Moderate limiting factor; 4 = Severe limiting factor; 5 = Extreme limiting factor.

Table 6. Criteria of Soil Quality in Mendoyo Subdistrict

HLU	PP	CP	BP	Cumulative Weight (SQI)	Soil Quality
I	14	13.6	3	30.6	Poor
II	8	10.3	3	23.3	Good
III	8	10	4	22	Good
IV	10	10	3	24	Good
V	6	9	3	22	Good
VI	6	10.6	3	19.6	Very Good
VII	8	8	3	18.3	Very Good
VIII	6	10.3	3	19.3	Very Good
IX	6	10.3	3	19.3	Very Good
X	6	10.3	3	19.3	Good

Note: Cumulative Weight is addition for Physical Propertiy (PP); Chemical Property (CP); and Biological Property (BP).



(a) (b)

Figure 4. (a) Correlation and Regression of Parameter of Porosity and CEC, (b) Correlation and Regression of Parameter of Porosity and BD

3.3.1 Soil's Physical Properties

The physical properties affecting soil quality included soil texture, porosity, BD, and FC. The constraining factor in this research was soil texture as it was classified into the 'extreme' category, which did not have any other restricting factors. Soil texture refers to a balanced mixture of sand, clay, and silt. It is also perceived as an indication of the fineness or coarseness of soil grains (Isra *et al.*, 2019). In the correlation and regression tests, soil texture did not significantly affect the parameter of soil quality.

Moreover, the soil porosity showed a notable adverse impact on the CEC. The increase in porosity is inversely proportional to the increase in CEC. Porosity refers to the total volume of soil pores inside a given soil volume (Sumiyati *et al.*, 2024). The correlation between the two parameters is indirectly affected by the soil texture. (Rozi *et al.*, 2022) stated that soil texture composition has a role in determining high porosity, with the sand fraction being more prevalent than the clay and silt fraction. The higher the sand content in the soil texture, the higher the soil porosity (Nuharuddin *et al.*, 2020) and the lower the CEC content. The characteristics of soil pores are also essential in affecting the capacity of soil porosity (Masria *et al.*, 2020). Soil texture dominated by sand content will have large soil macro pores, leading to a decrease in water-holding capacity and an increase in soil porosity.

The analysis results showed significant negative correlation and regression between soil porosity and BD with values of 0.906 and 0.821 (Figure 5.1). It means that the higher the soil porosity, the lower the soil volumetric weight is, and vice versa. Budianto *et al.*, (2014) asserted that an increase in soil volumetric weight leads to a decrease in soil porosity. The increase in soil volume weight causes the soil compaction due to the reduction in macro pore space. This, in turn, hampers water infiltration into the soil, resulting in a loss in the soil's water-holding and water-transmitting capacity (Yuda *et al*., 2022).

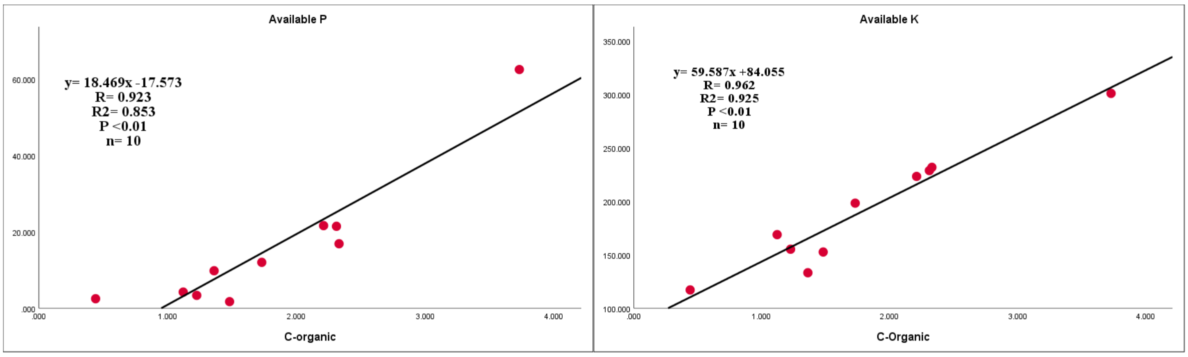
3.3.2 Soil's Chemical Properties

Soil chemical properties are part of the soil quality parameters of land that are observed through indicators of C-organic, soil pH, CEC, BS, and soil nutrients (total N, available P, available K). The analysis results indicated a wide range of C-organic and nutrient soil nutrients levels, varying from low to high. It proved that C-organic nutrient contents were the constraining factors in soil quality. The insufficient levels of C-organic and nutrients can be attributed to inadequate land management and imbalanced fertilizer input on rice and plantation fields.

The results of the correlation and regression of each parameter of soil chemical properties showed a statistically significant positive relationship between C-organic and available P, with values of 0.923 and 0.853, respectively. This implies that the increase in C-organic content is directly proportional to the available P. The results showed that the level of available P ranged from very low to moderate. Therefore, the C-organic also ranged from very low to moderate. These results indicated that total P did not contribute to the soil fertility. The low C-organic content indicated a low content of organic matter. Thus, it did not increase the available P. According to Imansari *et al*., (2018) the presence of organic matter, artificial fertilizers, and minerals in the soil has a significant impact on the P content. Decomposed organic waste will release plant nutrients and solvents for nutrients such as P, K and N (Lumbanraja *et al.*, 2023). The results of research by Wulantika *et al*., (2023) showed that providing chicken manure compost with banana stem local microorganisms (LMO) at a dose of 5 t ha-1 can increase the P content in the soil compared to the absence of any treatment.

The content C-organic also showed a significant positive correlation with available K, with values of 0.962 and 0.925, respectively. Laboratory analysis results indicated that the K value in rice fields ranged from low to high, whereas that in plantation fields ranged from medium to high. Agoesdy *et al*., (2019)showed that the K nutrient status in rice fields in five villages of Tanjung Morawa Subdistrict ranged from medium to high with a variation in K nutrients of 9.32 cmol kg^{-1} soil to 69.07 cmol kg^{-1} soil. The differences in K values on each land can be attributed to improper land management and differences in organic material input. Organic materials, apart from being a provider of K nutrients, can also act as a solvent, facilitating the availability of nutrients (Kusumawati, 2021). Balanced fertilization also affected the value of K. Research by Iqbal *et al*., (2019) and Syamsiyah *et al*., (2023) found that a combination of inorganic and organic fertilizers influences K availability.

The correlation and regression analysis between C-organic and total N did not yield statistically significant results, despite a favorable relationship between the two variables. The results showed that the total N value fell within the range of extremely low to moderate. The low total N content included the low content of soil organic matter. Naturally, the total N content is closely related to the availability of soil organic matter or the C-organic value of the soil (Fadilla *et al*., 2024). The nature of nitrogen in the form of NO_3, which is susceptible to being washed away by water flow and rainwater, is also a contributing factor in the low total N in the soil. Fadilla *et al*., (2024) asserted that in mixed plantation areas, the potential for N loss (NO3) is significant due to its propensity to be carried away by water. The investigation revealed a strong positive correlation between the total N and C-biomass, with values of 0.683 and 0.467.



(a) (b)

Figure 5. (a) Correlation and regression of parameter of C-organic and availabel P, (b) Correlation and regressing of parameter of C-organic and available K.

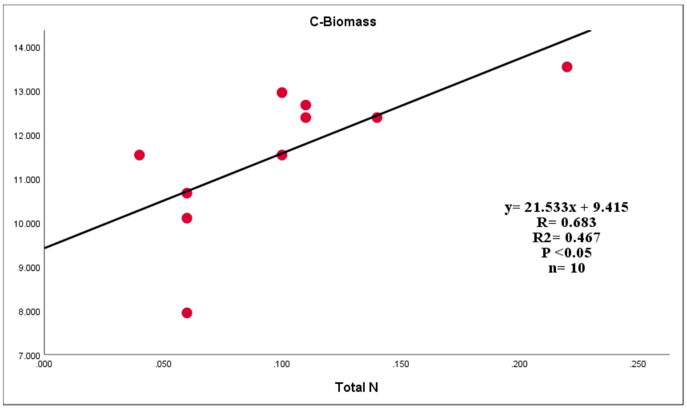


Figure 6. Correlation and regression of parameter of total N and C-biomass

3.3.3 Soil's Biological Properties

The soil biological property is part of soil quality observed through C-biomass parameters. The results of the C-biomass analysis showed significant constraints ranging from moderate to severe (Table 4.4). Figure 5.1 demonstrates a considerable positive correlation and regression between C-biomass and total N. The measurement of C-biomass aims to determine the activity of microorganisms in the soil. The presence of low levels of organic matter and soil in this research resulted in the C-biomass being classified into a low category. For optimal growth and development of soil microorganism, it is necessary to have adequate nutrients, accessible energy sources, and suitable pH levels (Niswati *et al.*, 2019). Nitrogen serves as an energy source facilitating the growth of soil microorganisms. (Niswati *et al.*, 2019) reported that long-term N fertilization with a dose of 50 kg N ha without tillage can lead to an increase in C-biomass one month after planting. Organic matter, although not significant in correlation and regression, shows a positive relationship. Soniari and Atmaja (2019) stated that the addition of organic materials contributes to the increasing number of microorganisms in the soil.

3.4 Recommended Doses for Balanced Fertilization for Specific Area

Balanced fertilization is based on soil fertility conditions and soil quality that focuses on constraining factors. The guidelines for achieving balanced fertilization in specific areas within Mendoyo Subdistrict, Jembrana, were based on The Regulation of the Minister of Agriculture Number 40 of 2007 and the Indonesian Soil Research Institute in 2021. Varied doses of balanced fertilization were applied based on the specific land use. This research focused on the land use which includes rice fields and plantation fields cultivating robusta coffee, cacao, coconut, and banana plants.

3.4.1 Rice Fields

The recommendations for N (Urea) fertilizer for rice fields were based on the productivity level of rice plants. In contrast, the recommendations for P and K fertilizers were based on the results of soil analysis. The P and K status of the soil were grouped into three classes, namely high, medium, and low. The suggested NPK compound fertilizer was NPK 15-15-15 fertilizer, referring to the lowest dose of P or K. So as to address any deficiencies, additional fertilizers in the form of N (Urea) and P (SP-36) or K (KCl) can be supplied individually. The use of organic materials in the form of manure or rice straw was determined by the C-organic content in the soil.

3.4.2 Plantation Fields

The fertilizer doses for plantation crops, including robusta coffee, cacao, coconut, and banana plants, were recommended to be measured in units of kg/tree/year. Moreover, the recommendations for single fertilizer doses and compound fertilizers was NPK 15-10-12 based on the P and K nutrient status of the soil. For robusta coffee and cocoa plants, in addition to NPK fertilizer, Kiserite fertilizer was highly suggested as it contained Mg and S. (Mg) is a nutrient needed by plants in large quantities since it boosts the formation of chlorophyll, which is the most important part of the photosynthesis process (Wahyuni and Manurung, 2020). For coconut plants, besides using Kiserite fertilizer, borax fertilizer is also advised. The inclusion of boron in borax fertilizer is crucial for promoting generative growth. It facilitates the growth of pollen tubes through carbohydrate and phenolic acid metabolism (Pereira *et al.*, 2021). Organic fertilizer is applied at the beginning of the planting season with a dose adjusted to the results of the soil C-organic analysis, which often falls within the moderate range.

Table 5. Recommended Doses for Balanced Fertilization of Rice Plants

HLU	Single Fertilizer (kg ha^{-1})				Compound Fertilizer+Single Fertilizer (kg ha^{-1})				Organic Fertilizer (t ha^{-1})
	Urea	ZA	SP-36	KCl	NPK 15-15-15	Urea	SP-36	KCl	
I	350	100	100	100	250	150	0	50	2
II	350	100	100	50	250	150	0	0	2
III	350	100	75	50	200	175	0	0	2
IV	350	100	75	50	200	175	0	0	2
V	350	100	100	50	250	150	0	0	2

Table 6. Recommended Doses for Balanced Fertilization of Robusta Coffee Plants

HLU	Single Fertilizer (kg ha^{-1} year^{-1})			Compound Fertilizer+Urea (kg ha^{-1} year^{-1})		Organic Fertilizer (kg plant^{-1} year^{-1})	Kieserite (kg ha^{-1})
	Urea	SP-36	KCl	NPK 15-10-12	Urea		
VI	265	135	145	665	50	15	95
VII	265	110	145	665	50	15	95
VIII	265	160	185	860	-	15	95
IX	265	160	185	860	-	15	95
X	265	160	185	860	-	15	95

Note: Keserite is single fertilizer containing magnesium and sulfur.

Tabel 7. Recommended Doses for Balanced Fertilization of Cacao Plants

HLU	Single Fertilizer ($kg\ ha^{-1}\ year^{-1}$)			Compound Fertilizer+Urea ($kg\ ha^{-1}\ year^{-1}$)		Organic Fertilizer ($kg\ plant^{-1}\ year^{-1}$)	Kieserite ($kg\ ha^{-1}$)
	Urea	SP-36	KCl	NPK 15-10-12	Urea		
VI	265	135	145	485	65	15	85
VII	265	110	145	475	65	15	85
VIII	265	160	185	590	25	15	85
IX	265	160	185	590	25	15	85
X	265	160	185	590	25	15	85

Tabel 8. Recommended Doses for Balanced Fertilization of Coconut Plants

HLU	Single Fertilizer ($kg\ ha^{-1}\ year^{-1}$)			Compound Fertilizer+KCl ($kg\ ha^{-1}\ year^{-1}$)		Organic Fertilizer ($t\ ha^{-1}$)	Kieserite ($kg\ ha^{-1}$)	Borax ($kg\ ha^{-1}$)
	Urea	SP-36	KCl	NPK 15-15-15	KCl			
VI	125	95	150	435	65	10	25	4
VII	125	75	150	435	65	10	25	4
VIII	125	115	225	560	75	10	25	4
IX	125	115	225	560	75	10	25	4
X	125	115	225	560	75	10	25	4

Note: borax is single fertilizer containing boron.

Tabel 9. Recommended Doses for Balanced Fertilization of Banana Plants

HLU	Single Fertilizer ($kg\ ha^{-1}\ year^{-1}$)			Compound Fertilizer+Urea ($kg\ ha^{-1}\ year^{-1}$)		Organic Fertilizer ($t\ ha^{-1}$)
	Urea	SP-36	KCl	NPK 15-10-12	Urea	
VI	125	95	150	1500	225	10
VII	125	75	150	1200	400	10
VIII	125	115	225	2850	-	10
IX	125	115	225	2850	-	10
X	125	115	225	2850	-	10

4. CONCLUSIONS

The results of further regression and correlation tests showed that C-organic and porosity were the most influential parameters in soil fertility and quality. Organic matter plays a crucial role in achieving balanced fertilization for specific areas. Furthermore, the presence of organic matter not only supplies nutrients but also enhances the soil's physical and biological properties. The statistical regression and correlation tests between porosity and volumetric weight have demonstrated the significance of total N and C-biomass in organic matter. It is advised to use a balanced combination of Urea, SP-36, KCl, and a high-dose organic fertilizer that complies with the regulations set by the Ministry of Agriculture and the Indonesian Soil Research Institute for specific locations in the research zone.

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