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SOIL QUALITY INDEX ANALYSIS UNDER HORTICULTURAL FARMING IN SUMANI UPPER WATERSHED

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ABSTRACT: The intensive use of land for farming and horticulture results in soil degradation. The loss of nutrient elements contributes to the decline in soil quality index. This study aimed to investigate the major factors that contribute to soil degradation in the in the upper section of the Sumani Basin. Soil quality index is obtained as an indicator of soil functions. Thus, this study used this parameter to investigate the factors that contribute to the decrease in soil fertility. A purposeful random sampling method was used to obtain samples from different sample points. The biophysical properties of the soil samples were analyzed in the laboratory at the Department of soil science. The Principal Component Analysis (PCA) of the samples were carried out by using a data processing application software (mini tap 17.0). These results were used to determine the Minimum Data Set (MDS) for each soil sample. This research study showed that the two types of soil obtained from the various sample points were inceptisol and andisol. The major factors that influence soil quality include bulk density, soil CEC, root depth, and soil texture. The soil sample obtained from the third farmland group (Group C) had the best soil quality.

Keywords: Horticulture, Quality index, Watershed upstream.

1. INTRODUCTION

Horticultural or vegetable farming in the upper watershed of Sumani, Solok is the main source of livelihood for people who live in the surrounding area. This area lies on the slopes of Mount Talang; it has fertile soils formed in volcanic ash. . Based on soil classification [1], the soil around the foot of the mountain is classified as andisol. This type of soil is black and has a high fertility. Thus, it supports various farming activities, especially the cultivation of vegetable crops (horticulture) which provide a decent source of livelihood to farmers.

However, if the fertile soil is not managed by good soil and water conservation principles, the fertility or quality level of the soil will decrease drastically. This will result in a decrease in productivity of the land and low acceptance of the peasant community. This turn of events may result in huge losses to farmers. Therefore, it is necessary to evaluate the soil fertility level in this area as well as the major factors that contribute to the decrease in soil fertility in the upper section of the Sumani Basin. The study conducted by [2] documented that quality evaluation is critical to the determination of the soil's ability to function as a growing medium that provides water and nutrients in the root zone of plants. Thus, this can be considered to be a solution in land management. The quality of land must be improved and maintained to ensure that vegetable farming in the area becomes sustainable.

Soil quality can also be defined as the ability of soils to function within ecosystems by supporting crop and animal productivity, maintaining/ improving water and air quality, and promoting human and environmental health [3], [4] [5]. Some experts have stated that the quality of the soil determines the amount of crops produced in each season. In addition, soil quality greatly affects crop yield because it determines the quality of nutrients absorbed by plant roots.

The soil acts as a store that provides nutrients and water to the root of plants. Thus, there is a need to investigate the physical, chemical and biological properties of the soil in order to determine the extent to which its condition supports current crop growth. The soil properties analyzed are the minimal properties that influence its quality or Minimum Data Set (MDS). Soil properties include soil texture, bulk density, total pore space, permeability, pH, Cation Exchange Capacity (CEC), and organic matter

2. MATERIALS AND RESEARCH METHODO-LOGY

2.1 Time and Location

his study was conducted during the periods of February, 2018 to June, 2018 at multiple sample points in the upstream watershed of the Sumani horticultural land, , Solok regency of West Sumatra (Figure 1). Soil Quality Indicator Analysis was carried out at the Laboratory of Soil Department, Faculty of Agriculture, University of Andalas.

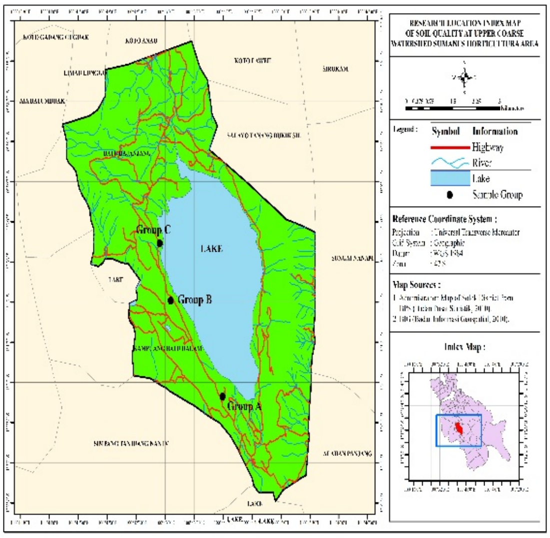

Fig. 1. Map of the Sumani Basin of Upper Section

2.2. Research Materials and Tools

The materials used in this study include chemical reagents used to analyze the physical, chemical and biological properties of the. The tools used to determine the soil quality for horticultural productioninclude the Global Positioning System (GPS), loops, maps, sample rings, knives, plastics, and label paper. The tools used for laboratory analysis of soil samples include the desiccator, oven, Erlenmeyer flasks, scales, analytical scales, goblets, spectrophotometers, Whatman filter papers, funnel, Kjeldhal tube, burette, distillation flask, and stative/ measuring pipette.

2.3. Research Methodology

A field survey was conducted to obtain both secondary and primary data. Secondary data was obtained from rainfall data, interview with the farmers and related officials in agricultural institutions. Primary data was obtained from the land samples collected at several points in the study location. Soil samples were collected using a purposeful random sampling technique. The samples were taken to the laboratory and analyzed for physical, chemical and biological properties. Soil samples were collected at a depth of 20 cm.

Table 1 Minimum Data Set (MDS) parameters for the analysis of soil quality at horticulture production centers, Sumani

Observation Variables	Variables	Methods
Soil Physical Characteristic	Texture	Pipette
	Permeability	Darcy's Law
	Infiltration	Horton
	Aggregate stability	Vilansky
	The effective depth of the roots	Bor belgi
	Bulk density	Volumetric
Soil Chemical Characteristic	H_2O pH	PH meter
	CEC	Washing with Ammonium
Soil Biological Characteristic	Soil organic material	Wakey and black

The location point of soil sampling was three groups of the horticultural farming around the lake, below and on the upper section of the Sumani Basin. (2) Secondary data about some aspects of horticultural farming and current condition of the area were obtained via the collection of data from several related agencies and the conduction of interviews with the farmers. The findings obtained from these interviews were scored and used as supporting information on horticultural productivity in the area. (3) The MSD parameters used in the determination of soil quality are listed in Table 1. These parameters were determined by using minitab 17.0.

The Principal Component Analysis (PCA) method was used to select the most appropriate indicator that would produce the data referred to as Principal Components (PC). The soil quality assessment was performed by using a soil quality index that was scored on selected variables of the PCA and the Minimum Data Set (MDS). The PC used as MDS had an Eigen value that is more than 1; the weightiest factor was selected as a principal component. The value of the selected indicator on each PC was multiplied by its scores to determine the soil quality index at each sample point. The score interval was 1 to 5 with a value of 0.1; 0.25; 0.5; 0.75; and 1. The higher the score of a variable, the higher the quality of the soil. The calculation of soil quality was done by multiplying the score of the variable by the weighted index [6]. According to [7], the assessment of soil quality can be calculated by using the formula for Soil Quality Index (SQI) or IKT;

$$SQI = \sum_{i=1}^{n} Wi \; x \; Si$$

Annotation:
SQI = Soil Quality Index
Wi = Weighting Factor
Si = Score Index

If the index value has been obtained, the soil quality can be determined using Table 2.

Table 2 Classes of Soil Quality

Soil Quality	Scale	Class
Very Good	0.8 – 1	1
Good	0.6 – 0.79	2
Fair	0.35 – 0.59	3
Bad	0.20 – 0.34	4
Very Bad	0 – 0.19	5

3. RESULTS AND DISCUSSION

3.1. Biophysical properties

The research location for this study was three farmland groups denoted as group A, B, and C. The type or order of the soil in each group were inceptisol, and andisol. Thable 3 showed the commodities grown in each farmland group were potatoes, red chilis, red onions, and carrots.

The description of the biophysical conditions of the soil in study area is shown in Table 4. The soil sample from group A had a sandy clay texture, Group B had a clay loam texture and Group C had a loamy texture. The bulk density was very low in al three groups, this places them in the fair criteria for soils. Based on the biophysical properties of the soil, they were considered as fertile. This is due to the origin of the soil's parent material.

Table 3 Farmer groups, types of soil, and cultivated crops

Location	Soil Classification USDA	Number of Sampling Points	Plant Type
Farmer Group A	Inceptisol	Three points	Potato Red Chili Carrot
Farmer Group B	Andisol	Three points	Red onion Red Chili Carrot
Farmer Group C	Inceptisol	Three points	Red onion Red Chili Carrot

Farming systems are cultivated continuously without any fallow or rest. This will have an impact on soil quality if farm management is poor. Based on the results of the study [8] stated that the causes of the decline in soil fertility include the washing away of nutrients and low soil organic matter. Furthermore, [8] suggested the conduction of integrated soil management (which utilizes organic fertilizer) to maintain the balance of nutrients in the soil. The results [9] show that changes in land use from secondary forests to fields cause land degradation due to the low content of soil organic matter and rapid decomposition.

3.2. PCA Analysis

The main components that greatly affect soil quality is shown in Table 5. Factors that act as a determinant of soil quality index had an Eigen value that is more than 1. The result of the PCA analysis revealed four component factors, namely PC1, PC2, PC3, and PC4.

Table 4 Biophysical characteristics of the soil on three farmland groups, upstream Sumani section

Famer group	Bulk density g/cm^3	Total of pore space %	Organic matter %	depth (cm)	sand %	dust %	clay %	Hydrology conductivity cm/jam	CEC (cmol/kg)	PH H20
A	0.5	80	1.3	15.7	46.9	24.8	28.3	35.0	17.1	6.4
B	0.8	70	0.5	29.3	13.7	55.6	30.7	30.2	10.0	6.1
C	0.8	70	0.4	16..3	44.4	32.8	22.9	20.3	9.3	6.7

Table 5 Principal component analysis result

Eigenvalue	2.9210	2.6160	2.2153	1.5912
Proportion	0.266	0.238	0.201	0.145
Cumulative	0.266	0.503	0.705	0.849

Variable	PC1	PC2	PC3	PC4
Infiltration capacity	0.409	0.217	-0.039	-0.236
Bulk density	0.527	-0.027	-0.106	0.282
Total of pore space	- 0.527	0.027	0.106	-0.282
Organic matter	0.014	0.317	0.482	0.143
Soil depth	0.028	0.112	0.614	-0.009
Sand	-0.019	0.477	-0.093	-0.483
Dust	0.384	-0.294	0.218	-0.106
Clay	-0.352	-0.121	-0.130	0.509
Permeability	-0.057	-0.375	0.217	-0.370
CEC	-0.034	0.425	0.300	0.353
H2O pH	0.011	0.436	-0.396	-0.014

3.3. Soil Quality Index

The Soil Quality Index (SQI) in each farmland group was determined the multiplication of the value of the selected soil properties score (Si) with the weighted index (Wi). The weighted index is the highest value in each selected PC column. Based on the results of major component analysis (PCA), the soil properties used in the determination of soil quality index were bulk density (BV), pH, rooting zone depth, and clay fraction.

Bulk density is an important principal component which determines root development in the plant root zone. The root zone is another important component because the depth of the soil determines the roots' ability to absorb nutrients.

According to [10], the root zone (a.k.a. rizhophere) is heavily influenced by root exudates. The high activity of micro-organisms in the area makes the soil fertile

The pH and texture of the soil determines the availability of nutrients for plants.

The soil pH and clay fraction strongly determine its cation exchange capacity (CEC). CEC is an important soil property that indicates whether the land is fertile or not. A high soil CEC indicates that the soil will be effective in providing nutrients to plants, especially nutrients from fertilization.

Macro and micro elements will not be available to plants if cation exchange capacity is low, and vice versa. This is because CEC holds and prevent the nutrient elements from being washed away. The presence of organic matter greatly influence the cation exchange capacity of soils. This is because organic materials have a high CEC. Thus, they can increase the cation exchange capacity by three folds compared to mineral soil. In addition, cation exchange capacity is influenced by the type and content of clay in the soil [11]. Thus, these four variables are referred to as the minimum data set.

Refer to Eq.(1) is obtained the results of the calculations of soil quality (Tabel 7) indices in group A ranged from medium to very good (Table 7). There were also variations in the soil quality index between different sampling points. This was due to the cultivation of different types of vegetable crops in each sample point (i.e. potatoes, red pepper and carrots).

Table 6 Calculated value of soil quality index in each farmland group based on PC factors.

Location	SQI	S1 BV	W1 BV	S2 sand	W2 sand	S3 d soil	W3 d soil	S4 CEC	W4 CEC
			0.527		0.477		0.614		0.353
Group A	0.79	0.25		0.5		0.25		0.75	
	0.71	0.1		0.5		0.25		0.75	
	0.44	0.25		0.25		0.25		0.1	
Group B	0.88	0.25		0.75		0.5		0.25	
	0.84	0.1		0.5		0.75		0.25	
	0.83	0.5		0.5		0.25		0.5	
Group C	0.66	0.25		0.1		0.5		0.5	
	0.85	0.25		0.5		0.5		0.5	
	0.68	0.25		0.75		0.25		0.1	

Annotation; SQI (Soil quality Index), BV (soil bulk density), d (soil depth), CEC (Cation Exchange Capacity), S (score factor of value), W (weighting factor index).

Table 7 Calculated values of Soil Quality Index in each location

Location	Soil Quality Index	Criteria
Group		
A1	0,85	Very Good
A2	0,71	Good
A3	0,43	Fair
B1	0,88	Very Good
B2	0,96	Very Good
B3	0,83	Very Good
C1	0,66	Good
C2	0,67	Good
C3	0,67	Good

The three groups of farmland had a relatively high soil quality index and met the good criteria for soils. This shows that there is a good land management input from farmers. The types of plants cultivated include red chili, onions, and carrot (Table 3). The soil quality index in farmland group B (Table 5) was very good. The commodities planted on the land include red chili, carrots, and onions. According to [12], the high variability of soil characteristic is due to the different agricultural management of the soils (organic or traditional; arable, scrublands or woodland), cultivation of different crops (barley, corn, green manure, meadow, sugar beet, tomato, wheat and alfalfa) and fertilization (traditional or sewage sludge).

The land quality index of the three horticultural farming groups were different (Table 7). This indicates that there are differences in land location, soil type, plant type, and soil maintenance management, especially the application of principal soil conservation.

The soil characteristics of each farmland group influenced the morphology of the plants grown in each sample point. Potato, carrot and onion plants need good soil conditions (such as aeration, good organic matter, presence of micro- and macro-nutrients) for optimum growth. On the other hand, red chili plants have roots that penetrate deeply into the soil to absorb nutrients. A study conducted by [13], showed that the presence of low soil pH and high clay fraction in ultisol affected the growth of peanuts, corn, and soybean plants. It resulted in the poor development of the plants' roots. Contrastingly, plants cultivated on soil treated with compost and manure had well-developed roots and higher crop yield.

Poorly treated soils do not have the essential nutrients required for plant growth. It also has a higher tendency to lose its nutrients during water erosion, thereby resulting in the low saturation of the base. [14]. The percentage of basic saturation required for optimal soil productivity is ≥80%. Soils with a basic saturation below 40% results in the poor growth of plants [15] Conservation efforts toward the prevention of soil erosion on horticultural farmland involve the application of soil conservation methods on slopes (e.g. the cultivation of crops according to the contour and the creation of a gulud terrace). Some research studies have documented that the cultivation of seasonal crops using contours and royal grass strips can reduce soil erosion by 45 percent in community farms around the Singkarak Water Capture Area [16].

4. CONCLUSIONS

This research study showed that the two types of soil obtained from the various sample points were Inceptisol and Andisol. The major factors that influence soil quality include bulk density, soil CEC, root depth, and soil texture. The soil sample obtained from the third farmland group (Group C) had the best soil quality.

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6. REFERENCES

[1] USDA, 2014. Key to Soil Taxonomy. Soil Survey Staff, USDA, Ames. USA.

[2] Larson, W. E. and Pierce, F. J. 1991. Conservation and Enhancement of Soil Quality. In Dumanski, J, E. Pushparajah, M. Latham and R. Myers, (ed). Evaluation for Sustainable Land Management in the Developing World. *Publ. International Board for Soil Research and Management, Bangkok, Thailand*. Vol. 2:175-204.

[3] Wander Michelle M, Gerald L Walter, Todd M Nissen, German A Bollero, Susan S. Andrews, Deborah A Cavanaugh-Grant 2002. Soil quality: science and process. Agronomy Journal 94.

[4] Karlen, D.L., M.J. Mausbach, J.W. Doran, R.G. Cline, R.F. Harris, and G.E. Schuman. 1997. Soil quality: A concept, definition, and framework for evaluation. Soil Sci. Soc. Am. J. 61:4 10.

[5] Weil, R.R. and F. Magdoff. 2004. Soil Organic Matter in Sustainable Agriculture: Significance of Soil Organic Matter to Soil Quality and Health. CRC Press. Florida.

[6] Pratono, S. A. C., Supriyadi, and Purwanto. 2011. Zoning of Rice Field Quality in Industrial Area of Bengawan Solo Watershed Area of Karanganyar Regency. Journal of Soil Science and Agroklimatologi 8 (1) : 1-12

[7] SQI, 2001. *Guidelines for Soil Quality Assessment in Conservation Planning*. Soil Quality Institute. Natural Resources Conservation Services. USDA.

[8] A.Kasno, J.S. Adiningsih, Djokosantoso and Earn Nursyamsi. Integrated nutrient management for improving and maintaining productivity of dry land to sour. Pros. No. 14. Land Research 1998. ISSN. 0854-5588

[9] Alda 2018. Determination of Soil Quality Index Based on Soil Physical Characteristic on Various Land Use in Sub-watershed of Batang Arau Hulu "so that further can be known the appropriate management to maintain and improve upstream function of Batang Arau watershed. Bachelor's Thesis Agriculture Faculty of Agriculture Universitas Andalas.

[10] Soemarno. 2010. Systems Approach and Modeling. Post Graduate Program Universitas Brawijaya. Malang.

[11] Tan, Kim h. 1998. The basics of soil chemistry. Yogyakarta: Gadjah Mada University Press.

[12]. Aspetti G.P., Boccelli Raffaella, Ampollini Danio, Del Re Attilio A.M., Capri Ettore . 2010. Assessment of soil-quality index based on microarthropods in corn cultivation in Northern Italy Jounal Ecological Indicators 10 (2010) 129–135

[13] Aprisal. 2000. The study of the reclamation of imperata marginal land and integrated farming system modesl for sustainable agriculture development in transmigration area Pandan Wangi Peranap Riau. Disertation of PhD at griculture of University Bogor.

[14] A & L Canada Laboratories Inc. in 2002. Understanding cation exchange capacity and% base saturation. Fact sheet No. 54. London.

[15 Arsyad.S. 2010. Konservasi Tanah dan Air. IPB Press.

[16] Aprisal, Bujang Rusman, Refdinal. 2013. Land Management in building Conservation farming for the integration of food security in the rural catchment Singkarak. Pros. No.1. National seminar on Soil and Water Conservation Society. Palembang 6-8 November 2013. ISBN: 978-602-70116-0-1.