JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
ISSN: 2339-076X (p); 2502-2458 (e), Volume 8, Number 2 (January 2021): 2559-2568
DOI:10.15243/jdmlm.2021.082.2559

Research Article

The effect of land use on soil quality in Giriwoyo Sub-district, Wonogiri Regency

Mujiyo Mujiyo[1*], Yosua Yoga Setyawan[2], Aktavia Herawati[1], Hery Widijanto[1]

[1] Department of Soil Science, Faculty of Agriculture, Universitas Sebelas Maret, Jl. Ir. Sutami No. 36A, Surakarta 57126, Indonesia
[2] Department of Agrotechnology, Faculty of Agriculture, Universitas Sebelas Maret, Jl. Ir. Sutami No. 36A, Surakarta 57126, Indonesia

[*]corresponding author: mujiyo@staff.uns.ac.id

Received 9 September 2020, Accepted 11 November 2020

Abstract: Determination of soil quality in Giriwoyo Sub-district, Wonogiri Regency, will generate a Soil Quality Index which can be used as a reference for soil cultivation for optimal productivity. This research was a descriptive exploratory with a survey approach. The survey area consisted of 12 land mapping units (LMU) with 3 replications for each LMU. Determination of LMU based on soil type, land use, slope and rainfall. The parameters used were BD (bulk density), porosity, organic C, pH, CEC (cation exchange capacity), BS (base saturation), available P, available K, total N, and MBC (microbial biomass carbon) that represented the physical, chemical and biological properties of the soil. Principal Component Analysis (PCA) analysis was performed to obtain the Minimum Data Set (MDS). The Soil Quality Index (SQI) at each LMU was calculated by multiplying the PCA result score (Wi) with the score for each selected indicator (Si). The result showed that the Soil Quality Index at each LMU was low. The highest Soil Quality Index was found in fields land use with an SQI of 0.34. The soil indicator that limited the soil quality was available P.

Keywords: *land use, soil quality, soil quality index*

To cite this article: Mujiyo, M., Setyawan, Y.Y., Herawati, A and Widijanto, H. 2021. The effect of land use on soil quality in Giriwoyo Sub-district, Wonogiri Regency. J. Degrade. Min. Land Manage. 8(2): 2559-2568, DOI: 10.15243/jdmlm. 2021.082.2559.

Introduction

Soil quality is the capacity of a soil to function (Doran et al., 1994; Karlen et al., 1997; Shukla et al., 2006) and collection of various soil indicators, both physical, chemical and biological (Reeves, 1997). Soil quality is also considered a key element of sustainable agriculture (Larson and Pierce, 1994). Soil quality combines physical, chemical and biological soil elements and their interactions. Soil quality includes not only productivity and environmental protection but also food security and human and animal health (Seker et al., 2017). Soil quality is also related to ecological quality and the health of living things. Good soil quality is the optimal soil condition which is described by the physical, chemical and biological characteristics of the soil, which is optimal and can have high and sustainable productivity. Soil quality indicators consist of inherent and dynamic indicators. Inherent is an indicator of soil quality that is difficult to change; otherwise, the dynamic can change due to land management.

Land is one of the relatively incorrigible natural resources that its users must observe its permanence. Agricultural land use often fails to notice that land in one place will be different from elsewhere, as suggested by Prasetyo and Suriadikarta (2006). Improper agricultural management would make crops less productive (Sutanto, 2005). The decline in soil quality is indicated by changes in physical, chemical, and biological properties (Reijntjes et al., 1999).

Excessive use of fertilizers, use of pesticides and improper irrigation as well as improper agricultural management can cause soil quality degradation. Soil quality improvement can be made by conserving the land properly, as well as the addition of organic matter. Organic farming management produces soil quality one level higher than conventional agricultural management. Increasing soil organic C can increase nutrient availability (Parras-alcántara et al., 2017).

Giriwoyo Sub-district has a hilly area. The research location had a slope ranging from 6% to 40% and an average height of more than 500 m asl (above sea level). Slope and altitude are considered topographical factors, where slopes that have a steeper slope with a high altitude will increase the surface flow velocity or trigger landslides. According to the research results of Herawati et al. (2018), Slope is the most influential factor in soil degradation because it causes soil erosion. Every year there is a change in the use of forest land to agricultural land to expand the cultivation area. Measurement of soil quality in agriculture should not only be limited to productivity objectives because, in fact, but the emphasis on productivity has also resulted in soil degradation. The development of the land would have a distinct impact on the soil characteristics both physically, chemically and biologically that would have an impact on soil fertility and quality.

The total area of degraded land in Giriwoyo Sub-district is 6,227.396 ha, of which 349 ha are classified as critical, and 5,878.822 ha are classified as less critical (BPS Wonogiri, 2012). Erosion and poor land management are the causes of land degradation. The research results of Setyawanti (2014) showed that the greatest value of erosion rate in Giriwoyo sub-district using the USLE method was 564.355 tons/ha/year and the greatest value of erosion rate using the plot method was 115.895 tons/ha/year. Erosion also causes silting of reservoirs in downstream.

In 2019, Giriwoyo Sub-district was one of the eight sub-districts in Wonogiri Regency, affected by drought and was designated as a drought emergency area (Perdana, 2019). The drought resulted in food shortages. Drought can lead to a long-term decline in productivity in agriculture (Riptanti et al., 2018). Agricultural cultivation experiences disruption such as water shortages and harvest times which require a longer time, therefore the cultivation of agricultural commodities in Giriwoyo Sub-district is not running optimally. Insufficient water on agricultural can lead to crop failure and disrupt farmers' livelihoods (Pramudya et al., 2016). This is due to the disruption of the hydrological balance in the watershed due to land degradation (Miardini and Susanti, 2016).

It is necessary to do research in Giriwoyo Sub-district because there is still no research on soil quality in Giriwoyo Sub-district so that it becomes important information for Giriwoyo Sub-district to determine soil quality in the area. Soil quality calculations are determined based on the Soil Quality Index (SQI). Soil Quality Index values will be presented in the form of soil quality maps. Soil quality maps will make it easier for farmers or those with an interest in determining sustainable cultivation. This research was conducted to determine the Soil Quality Index and the effect of land use on soil quality in Giriwoyo Sub-district, Wonogiri Regency. Soil Quality Index is used as a reference for soil cultivation in any land use to achieve optimal productivity.

Material and Methods

This research was conducted from July 2019 to March 2020. The survey was conducted in Giriwoyo Sub-district, Wonogiri Regency. Laboratory analysis was carried out at the Laboratory of Soil Chemistry, Soil Physics, and Soil Biology, Faculty of Agriculture, Sebelas Maret University. Most of Giriwoyo Sub-district is included in the mountain range of a thousand which is dominated by limestone and is a spring from the Bengawan Solo river. The area of Giriwoyo Sub-district has an area of 10,060.13 ha and most of the population works as farmers. Most of the land uses in Giriwoyo Sub-district are paddy fields (1466.9 ha) and moorland (4575.88 ha).

The research stages consisted of: (1) determination of Land Mapping Unit; (2) field survey; (3) laboratory analysis; (4) determination of Minimum Data Set (MDS); (5) determination of Soil Quality Index (SQI) and mapping SQI; and (6) statistical analysis. The determination of Land Mapping Unit was made by overlaying a map of soil types, slope map, rainfall map and land use map. The survey area consists of 12 Land Mapping Units (LMU) with three replications so that there were 36 sampling points (Figure 1). The indicators observed represented the physical, chemical, and biological properties of the soil (Table 2). The indicators observed to determine the soil quality index included physical, chemical and biological soil properties. Indicators of soil physical properties consisted of bulk density (ring sample method) and porosity (ring sample method). Indicators of soil chemical properties consisted of organic C (Walkley and Black method), soil pH (pH meter with soil to water ratio 1:10), cation exchange capacity (extraction

NH_4OAc 1N pH 7), base saturation (extraction NH_4OAc 1N pH 7), available K (extraction NH_4OAc 1N pH 7), available P (Olsen method), total N (Kjeldahl method), and soil biological indicator consisted of microbial biomass carbon (fumigation). The Minimum Data Set (MDS) was determined using statistical applications to generate the correlation values. The highest correlation value was $p < 0.01 - \leq 0.05$. Furthermore, data having the highest level of sensitivity obtained are called Principal Component Analysis (Table 2). The main component analysis generated PC (principal component) data or the main component. The PC data were used to determine the Minimum Data Set (MDS) of soil quality.

Table 1. Criteria for LMU (Land Mapping Unit) in Giriwoyo Sub-district, Wonogiri Regency.

LMU	Type of soil	Slope (%)	Rainfall (mm/year)	Land use
1	Inceptisols	0-8	1750	Paddy Fields
2	Inceptisols	0-8	2250	Paddy Fields
3	Inceptisols	9-15	2250	Paddy Fields
4	Inceptisols	16-25	2250	Paddy Fields
5	Inceptisols	9-15	1750	Fields
6	Inceptisols	9-15	2250	Fields
7	Inceptisols	16-25	2250	Fields
8	Inceptisols	26-40	2250	Fields
9	Inceptisols	26-40	2250	Bush fields
10	Mollisols	9-15	1750	Moorland
11	Mollisols	9-15	2250	Moorland
12	Inceptisols	9-15	2250	Moorland

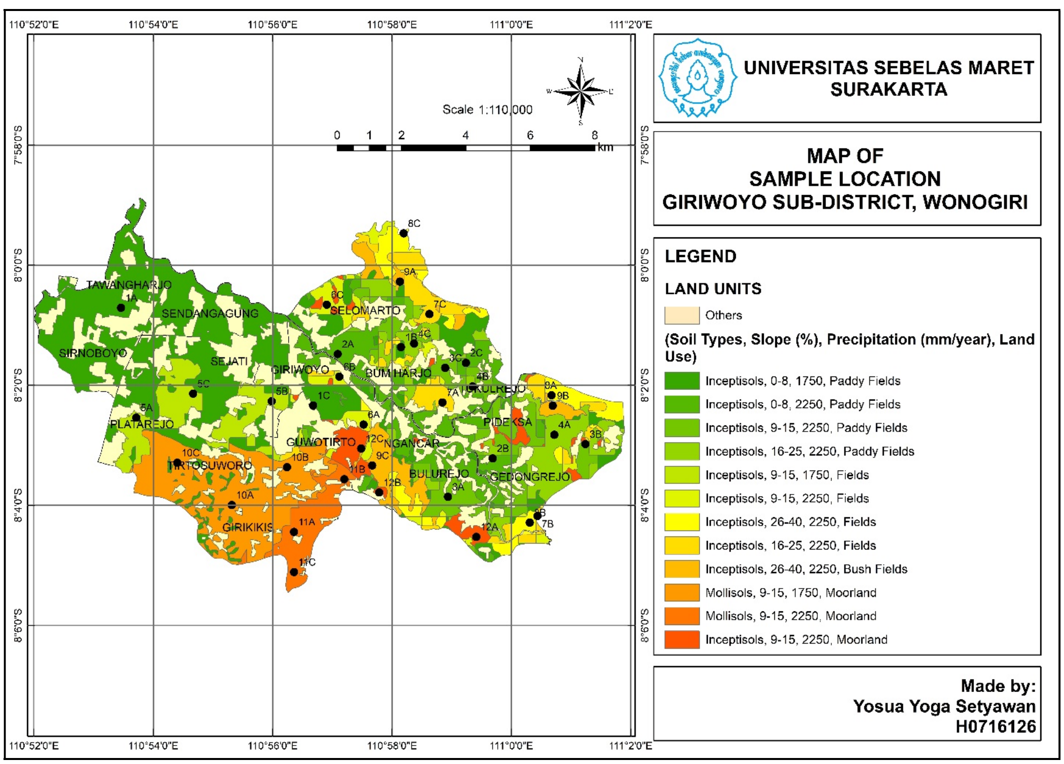

Figure 1. Map of sample location Giriwoyo Sub-district.

Table 2. Analysis of minimum data set.

Eigenvalue	2.4847	2.0452	1.5243	1.0160
Proportion	0.248	0.205	0.152	0.102
Cumulative	0.248	0.453	0.605	0.707
Eigenvectors				
Variable	PC1	PC2	PC3	PC4
BD	-0.455	0.109	-0.225	-0.024
Porosity	-0.313	-0.233	0.171	**0.553**
pH	**0.502**	0.101	-0.117	-0.154
Available P	0.284	-0.287	**0.276**	-0.215
Available K	-0.295	-0.046	0.211	-0.631
Total N	**0.468**	0.064	-0.254	0.046
CEC	0.033	-0.613	-0.337	-0.024
BS	0.046	**0.634**	0.233	0.124
Organic C	0.231	-0.185	**0.453**	0.398
MBC	-0.015	0.151	-0.591	0.222

Remarks: PC1 = pH and total N (correlated), PC2 = BS (independent), PC3 = organic C dan available P (independent), PC4 = porosity (independent), BD = bulk density, BS = base saturation, CEC = cation exchange capacity.

The selected PC is a PC that has an eigenvalue ≥1 (Kasier, 1960; Chandel et al., 2018). For each selected PC, some of the highest values were taken and then used as the weight index of the indicator on the calculation of Soil Quality Index. In this study, PC1 to PC4 were PCs that met the requirements to become a data set with a cumulative 70%, meaning that from 12 indicators only 6 indicators were used to determine the Soil Quality Index. Indicators used as MDS Soil Quality were determined by the highest value on each PC which had been adjusted based on the longest plot and predetermined criteria (PC1 to PC4). The indicators with the highest values on PC1 to PC4 were pH, total N, base saturation, organic C, available P and porosity. There were 6 parameters selected as Minimum Data Set (MDS) of 10 parameters which correlated very well with r ≥ 0.50. The Soil Quality Index (SQI) was calculated by multiplying Weight Index (Wi) and Score Index (Si) of the selected indicators (Mukhopadhyay et al., 2014). The way to determine the scoring index is by adjusting the results of the laboratory analysis against the scoring benchmarks according to Lal (1994); Wander et al. (2002); BPT (2005) (Table 3). The Weight Index was determined by dividing the value of the proportion with the cumulative value of each MDS derived from the results of the PCA analysis (Table 4). The calculation of soil quality was made by adding up the variable scores that have been multiplied by the weight index (Supriyadi et al., 2017) (equation 1).

Table 3. Score index of soil quality indicators.

Indicator	**Unit**	**Scoring Index (Lal, 1994)**				
		5	**4**	**3**	**2**	**1**
Bulk Density	g/cm^3	>1.5	1.4-1.5	1.3-1.4	1.2-1.3	<1.2
MBC	mg C/kg	>450	300-450	200-300	100-200	<100
		Scoring Index (Wander et al., 2002)				
		1	**2**	**3**	**4**	
Porosity	%	<15	15-30	30-40	40-60	
Available P	ppm	<16.8	16.8-33.6	33.6-44.8	>44.8	
pH	-	< 4	4-5	5-6	6-7	
CEC	(cmol(+)/kg)	<20	20-38	38-50	>50	
Organic C	%	<0.5	0.5-1	1-4	>4	
		Scoring Index (BPT, 2005)				
		1	**2**	**3**	**4**	
Base Saturation	%	<20	20-50	50-80	>80	
Available K	(cmol(+)/kg)	<0.4	0.4-0.7	0.7-1	>1	
Total N	%	0.1	0.1-0.3	0.3-0.5	>0.5	

Remarks: CEC = cation exchange capacity.

Table 4. Weight Index of MDS.

MDS	**Proportion**	**Cumulative**	**Wi**
pH	0.124	0.707	0.18
Total N	0.124	0.707	0.18
Base Saturation	0.205	0.707	0.29
Organic C	0.152	0.707	0.21
Available P	0.152	0.707	0.21
Porosity	0.102	0.707	0.14

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

where:

SQI	=	Soil Quality Index
Si	=	Score index of the selected indicators (Lal, 1994; Wander et al., 2002; BPT, 2005)
Wi	=	Weight index of selected indicators
n	=	Number of soil quality indicators

The soil quality was classified according to Cantu et al. (2009) (Table 5), in which the classification of soil quality is represented by numbers 1 to 5. The scores indicate soil quality classes from very good to very low soil quality.

Table 5. Classification of soil quality.

Soil Quality Index (SQI)	Score	Soil Quality Class
0.80-1	1	Very good
0.60-0.79	2	Well
0.35-0.59	3	Moderate
0.20-0.34	4	Low
0-0.19	5	Very low

Results and Discussion

Soil quality is measured based on observations of the dynamic conditions of soil quality indicators (Tables 6 and 7). Measurement of soil quality indicators generates a soil quality index which is calculated based on the value and weight of each soil quality indicator. Soil quality indicators are selected from the properties that indicate the functional capacity of the soil. Based on the soil function to be assessed, several appropriate indicators are selected. According to Partoyo (2005), the selection of indicators is based on the concept of a Minimum Data Set (MDS), which is as little as possible but can meet the need.

Soil quality index in Giriwoyo Sub-district is low with the average value of SQI for types of land uses is 0.32 (Table 9). Fields land use has the highest SQI value of 0.34, followed by bush fields (0.33) and moorland (0.31). Land use with the lowest SQI is paddy fields with SQI value of 0.30. The low soil quality index is due to the low available soil P. The low available P may be caused by high base saturation in the soil. In soils with high base saturation, phosphorus is fixed by Ca^{2+} (Sanchez, 2019). Some areas in Giriwoyo Sub-district are karst areas and dominated by limestone. Wibowo et al. (2019) stated that high Ca content in karst areas makes relatively low P availability. The differences in SQI indicate the influence of land use systems on soil quality.

The One Way Anova test results showed that land use had a significant effect on the soil quality index (F = 2.80; P-value = 0.05; n = 36), while slope (F = 0.09; P-value = 0.97; n = 36), soil type (F = 0.64; P-value = 0.43; n = 36), and rainfall (F = 1.10; P-value = 0.30; n = 36) had no significant effect on the Soil Quality Index. Land use can affect quality through changes in soil physical and chemical properties (Tematio et al., 2011). Changes in land-use systems can cause long-term and large-scale changes in soil structure and microbial activity in biological processes that affect soil quality (Xiao et al., 2017).

Table 6. Soil quality indicators (bulk density, porosity, organic C, pH, CEC) in Giriwoyo Sub-district, Wonogiri Regency.

LMU	Land Use	Soil Quality Indicator				
		Bul Density (g/cm^3)	Porosity (%)	Organic C (%)	pH	CEC (cmol(+)/kg)
1	Paddy Fields	1.60	25.9	3.50	6.70	14.71
2	Paddy Fields	1.46	27.0	3.82	6.34	8.88
3	Paddy Fields	1.79	26.9	1.51	5.95	11.92
4	Paddy Fields	1.94	21.9	2.42	6.42	10.12
5	Fields	1.33	32.9	3.98	7.04	12.96
6	Fields	1.67	34.2	4.17	7.56	8.69
7	Fields	1.38	37.0	2.49	7.52	8.08
8	Fields	1.67	31.3	2.5	6.70	9.74
9	Bush Fields	1.55	24.4	2.75	7.57	12.22
10	Moorland	1.29	46.1	1.94	7.34	11.76
11	Moorland	1.66	19.9	1.60	7.45	9.55
12	Moorland	1.51	33.0	1.89	6.85	6.59

Remarks: LMU = Land Mapping Unit; CEC = cation exchange capacity.

Table 7. Soil quality indicators (base saturation, N content, available P, available K, microbial biomass carbon) in Giriwoyo Sub-district, Wonogiri Regency.

LMU	Land Use	Soil Quality Indicator				
		Base Saturation (%)	N (%)	Available P (ppm)	Available K (cmol(+)/kg)	MBC (mg C/kg)
1	Paddy Fields	42.30	0.31	2.97	0.034	0.30
2	Paddy Fields	55.01	0.35	9.56	0.034	0.65
3	Paddy Fields	33.83	0.25	6.65	0.035	0.41
4	Paddy Fields	46.88	0.37	1.65	0.039	0.28
5	Fields	39.61	0.49	21.18	0.031	0.20
6	Fields	58.39	0.59	4.61	0.033	0.28
7	Fields	52.11	0.38	8.91	0.036	0.11
8	Fields	57.03	0.38	1.23	0.036	0.65
9	Bush Fields	57.64	0.69	1.96	0.031	0.84
10	Moorland	39.83	0.43	8.56	0.034	0.72
11	Moorland	48.70	0.38	6.75	0.032	0.42
12	Moorland	64.70	0.31	8.12	0.033	0.34

Remarks: LMU = Land Mapping Unit; MBC = microbial biomass carbon.

Table 8. Scoring index (Si) of MDS.

MDS	LMU (Land Mapping Unit)											
	1	2	3	4	5	6	7	8	9	10	11	12
pH	4	4	3	4	4	4	4	4	4	4	4	4
Total N	3	3	2	3	3	4	3	3	4	3	3	3
BS	2	3	2	2	2	3	3	3	3	2	2	3
Organic C	3	3	3	3	3	3	3	3	3	3	3	3
Available P	1	1	1	1	1	1	1	1	1	1	1	1
Porosity	2	2	2	2	3	3	3	3	2	4	2	3

Remarks: Scoring for selected indicators (Si) (Lal, 1994; Wander et al., 2002; BPT, 2005); BS = base saturation.

Table 9. Soil Quality Index Classification in Giriwoyo Sub-district, Wonogiri Regency.

MDS	Wi	LMU (Land Mapping Unit)											
		1	2	3	4	5	6	7	8	9	10	11	12
pH	0.18	4	4	3	4	4	4	4	4	4	4	4	4
Total N	0.18	3	3	2	3	3	4	3	3	4	3	3	3
BS	0.29	2	3	2	2	2	3	3	3	3	2	2	3
Organic C	0.21	3	3	3	3	3	3	3	3	3	3	3	3
Available P	0.21	1	1	1	1	1	1	1	1	1	1	1	1
Porosity	0.14	2	2	2	2	3	3	3	3	2	4	2	3
∑ Wi*Si		2.96	3.25	2.6	2.96	3.1	3.57	3.39	3.39	3.43	3.24	2.96	3.39
∑ Wi*Si/n		0.30	0.33	0.26	0.30	0.31	0.36	0.34	0.34	0.34	0.32	0.30	0.34
SQI		0.32											
SQI Class		Low											

Remarks: n (number of soil quality indicators); BS = base saturation.

Field land use has higher nutrient content and better porosity than other land uses. Fields land use in the research location is dominated by mixed cropping fields with various vegetation like mahogany (*Swietenia mahagoni*); combination teak tree (*Tectona grandis*) and sengon (*Albizia chinensis*); combination sengon (*Albizia chinensis*) and cassava (*Manihot esculenta*). Plant diversity has a positive relationship with increasing concentrations of available P and K in soil (Janssens et al., 1998) and other nutrients such as N, Ca and Mg (Holl, 1999). Plant diversity can also increase soil porosity, and root biomass is positively related to soil porosity (Fischer et al., 2015). Bush field has a higher nutrient content than other land use, especially for total N. It can be caused by the addition of natural organic matter through the litter. Bush field is dominated by grass. Litter and some dead roots from grass can be sources of carbon in the soil (Zhou et al., 2012). Plant residues in the soil will decompose and can increase soil organic carbon (Aminiyan et al., 2016). According to Dewi et al. (2018), organic C correlates with total N in the soil. Organic matter is decomposed by soil microorganisms to be converted into organic nitrogen. In addition, grass does not absorb many nutrients from the soil for growth, so the availability of nutrients in the soil is higher than the other land uses.

Paddy field has the lowest SQI compared to other land uses. pH, total N and base saturation in rice fields are lower than other land uses. This may be due to the high nutrient requirements for rice growth. The nutrients in the soil are used for continuous rice cultivation. High nutrient use is not matched by the addition of nutrients. The addition of nutrients only comes from fertilizers and the remaining straw, while at harvest time, all parts of the rice plant are taken away, and there is no return of nutrients to the soil. pH, total N and base saturation are important factors that influence nutrient availability in the soil. pH is related to the availability of other nutrients in the soil (Primadani, 2008) and the absorption of nutrients by plants (Winarso, 2005). Nitrogen is needed by the plant in large quantities. Irundu (2008) stated that soil with low macronutrient content is considered unhealthy. Nitrogen in the soil functions to help plant growth and provide protein in the soil. Organic systems carried out in rice fields can be used as a solution to improve soil quality (Mujiyo et al., 2018). Organic matter can increase the availability of soil nutrients such as total N, available P and available K (Angelova et al., 2013; Suntoro et al., 2018) required by rice. The addition of organic fertilizers that contain lots of nitrogen, such as Azolla to the soil can increase nitrogen availability in the soil (Dewi et al., 2018). Wibowo et al. (2014) explained that organic matter would increase the activity of microorganisms.

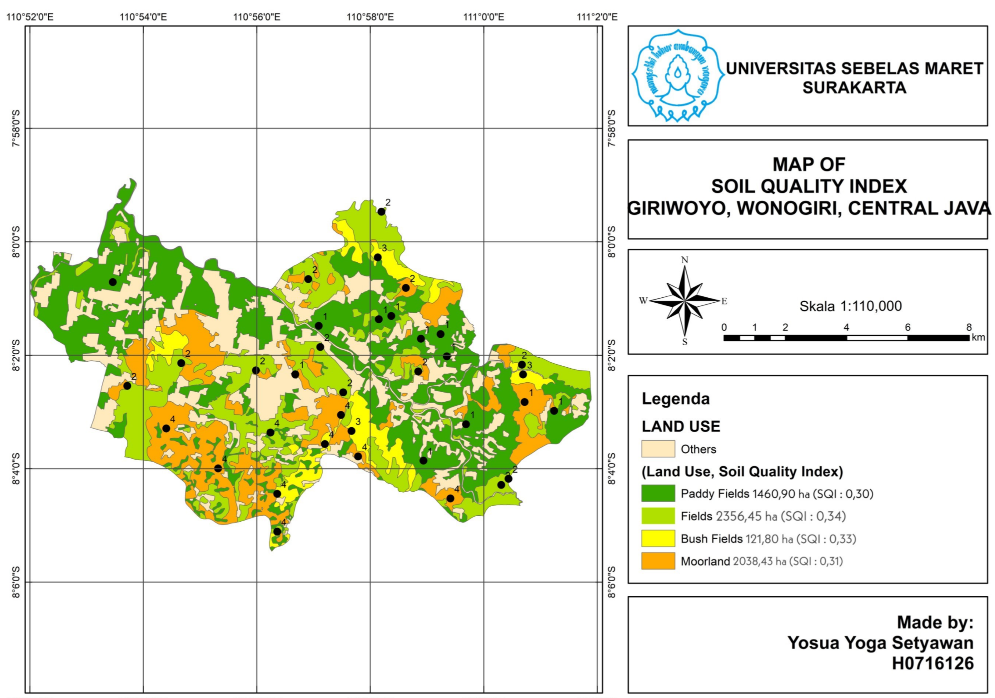

Figure 2. Map of soil quality index Giriwoyo, Wonogiri, Central Java.

The t-test results showed that the soil quality in the field was not significantly different from the soil quality in the bush fields and moorland. Fields land use and bush field in the research location have similar land structures. They both have tree vegetation; the difference is that bush fields are more dominated by grass than fields land use. Soil quality in the moorland not significantly different from the quality of the soil in the paddy fields. Both chemical and organic fertilizers are applied to the paddy fields and moorland at planting time. Paddy fields are cultivated twice a year, while moorlands are cultivated once a year because moorland in the research location is widely used for cassava cultivation. It is necessary to improve soil properties by managing soil organic matter by adjusting cropping patterns according to local conditions. Excessive use of chemicals without the support of organic inputs will reduce the level of soil quality (Juarti, 2016). Conservation farming systems aim to increase and maintain soil productivity. Efforts that can be made to maintain soil quality are soil conservation, crop rotation (Purwanto, 2009), the return of crop residues to the soil and fertilization management.

Conclusion

The SQI value in Giriwoyo Sub-district, Wonogiri Regency is low (0.32). Fields land use has an SQI of 0.34 (2356.45 ha), bush fields 0.33 (121.80 ha) and moorlands 0.31 (2038.43 ha), and paddy fields have the lowest SQI of 0.30 (1466.90 ha). The limiting factor for soil quality in Giriwoyo Sub-district, Wonogiri Regency is the available P.

Acknowledgement

This study was supported by Universitas Sebelas Maret under the research grant PNBP 2019-2020. The authors thank Ahmad Norri Prasetyo, Fajar Eko Susilo, Restu, Tiara Hardian and Widhi Larasati for their participation in the field survey and laboratory analysis.

References

Angelova, V.R., Akova, V.I., Artinova, N.S. and Ivanov, K.I. 2013. The effect of organic amendments on soil chemical characteristics. *Bulgarian Journal of Agricultural Science* 19(5): 958-971.

Aminiyan, M.M., Sinegani, A.A.S. and Sheklabadi, M. 2016. The effect of zeolite and some plant residues on soil organic carbon changes in density and soluble fractions: Incubation study. *Eurasian Journal of Soil Science* 5(1): 74-83, doi: 0.18393/ejss.2016.1.074-083.

Badan Pusat Statistik Wonogiri (BPS Wonogiri). 2012. Area of Critical Land Per District Year 2012. Retrieved from https://wonogirikab.bps.go.id/statictable/2015/01/07/32/luas-lahan-kritis-tahun-2012 (*in Indonesian*)

Balai Penelitian Tanah (BPT). 2005. *Technical Guidelines for Chemical Analysis of Soil, Plants, Water and Fertilizers*. Soil Research Institute. Bogor, Indonesia (*in Indonesian*).

Cantu, M.P., Becker, A., Bedano, J.C. and Schiavo, H.F. 2009. Disease surveillance using a hidden Markov model. *BMC Medical Informatics and Decision Making* 9: 173-178, doi: 10.1186/1472-6947-9-39.

Chandel, S., Hadda, M.S. and 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: 658-674, doi: 10.1080/00103624.2018.1425424.

Dewi, W.S., Wahyuningsih, G.I., Syamsiyah, J. and Mujiyo. 2018. Dynamics of N-NH_4^+, N-NO_3^-, and total soil nitrogen in paddy field with *Azolla* and biochar. *IOP Conference Series: Earth and Environmental Science* 142: 012014, doi: 10.1088/1755-1315/142/1/012014.

Dewi, W.S., Widijanto, H. and Nofiantoro, S. 2018. The potential of pineapple rotations to improve chemical properties of Ultisols. *Bulgarian Journal of Agricultural Science* 24: 99-105.

Doran, J.W. and Parkin, T.B. 1994. Defining an assessing soil quality. In: Doran, J. W., Coleman, D. C, Bezdicek, D. F. and Stewart, B.A. (eds), *Defining Soil Quality for a Sustainable Environment*, Soil Science Society of America, Inc, Madison, WI, USA, p.3-21, doi: 10.2136/sssaspecpub35.c1.

Fischer, C., Tischer, J., Roscher, C., Eisenhauer, N., Ravenek, J., Gleixner, G., Attinger, S., Jensen, B., de Kroon, H., Mommer, L., Scheu, S. and Hildebrandt, A 2015. Plant species diversity affects infiltration capacity in an experimental grassland through changes in soil properties. *Plant and Soil* 397: 1-16, doi: 10.1007/s11104-014-2373-5.

Herawati, A., Suntoro, Widijanto, H., Pusponegoro, I., Sutopo, N.R. and Mujiyo. 2018. Soil degradation level under particular annual rainfall at Jenawi District-Karanganyar, Indonesia. *IOP Conference Series: Earth and Environmental Science* 129: 012010, doi: 10.1088/1755-1315/129/1/012010.

Holl, K.D. 1999. Factors limiting tropical rain forest regeneration in abandoned pasture: seed rain, seed germination, microclimate, and soil. *Biotropica* 31: 229-242, doi: 10.1111/j.1744-7429.1999.tb00135.x.

Irundu, B. 2008. Assessment of Soil Quality in Several Types of Land Use in Liliraja District, Soppeng Regency. Universitas Hassanudin (*in Indonesian*).

Janssens, F., Peeters, A., Tallowin, J.R.B., Bakker, J.P., Bekker, R.M., Fillat, F. and Oomes, M.J.M. 1998. Relationship between soil chemical factors and grassland diversity. *Plant and Soil* 202: 69-78, doi: 10.1023/A:1004389614865.

Juarti, J. 2016. Analysis of Andisol soil quality index on various land uses in Sumber Brantas Village, Batu City. *Jurnal Pendidikan Geografi* 21(2): 131-144, doi: 10.17977/um017v21i22016p058 (*in Indonesian*).

Karlen, D.L., Mausbach, M.J., Doran, J.W., Cline, R.G., Harris, R.F. and Schuman, G.E. 1997. Soil quality: a concept, definition, and framework for evaluation (a guest editorial). *Soil Science Society of America Journal* 61, doi: 10.2136/sssaj1997.03615995006100010001x.

Kasier, H.F. 1960. The application of electronic computers to factor analysis. *Educational and Psychological Measurement* 20: 141-151.

Lal, R. 1994. Method and Guidelines for Assessing Sustainable Use of Soil and Water Resource in the Tropic. Soil Management Support Service USDA Soil Conservation. Washington DC, USA.

Larson, W.E. and Pierce, F.J. 1994. The dynamics of soil quality as a measure of sustainable management. Defining Soil Quality for a Sustainable Environment. *Proceeding Symposium*, Minneapolis, MN, 1992, doi: 10.2136/sssaspecpub35.c3

Miardini, A. and Susanti, P.D. 2016. Land use as a flood mitigation effort in Ngawi Regency. *Proceedings of the National Seminar on Geography of UMS 2016* (*in Indonesian*).

Mujiyo, Sunarminto, B.H., Hanudin, E., Widada, J. and Syamsiyah, J. 2018. The effect of organic paddy field system to soil properties. *IOP Conference Series: Earth and Environmental Science* 122, doi: 10.1088/1755-1315/122/1/012023.

Mukhopadhyay, S., Maiti, S.K. and Masto, R.E. 2014. Development of mine soil quality index (MSQI) for evaluation of reclamation success?: A chronosequence study. *Ecological Engineering* 71: 10-20, doi: 10.1016/j.ecoleng.2014.07.001.

Parras-alcántara, L., Lozano-garcía, B., Requejo, A. and Zornoza, R. 2017. Effects of land use change and management on SOC and soil quality in Mediterranean rangelands areas. *Geophysical Research Abstracts*, 19.

Partoyo. 2005. Analysis of soil quality index for sand dune agriculture land at Samas Yogyakarta.. *Ilmu Pertanian* 12(2): 140-151 (*in Indonesian*).

Perdana. 2019. Wonogiri Drought Emergency, Eight Districts with Water Crisis. Retrieved from https://radarsolo.jawapos.com/read/2019/09/13/155625/wonogiri-darurat-bencana-kekeringan-delapan-kecamatan-krisis-air (*in Indonesian*).

Pramudya, Y., Komariah, Dewi, W.S., Sumani, Mujiyo, Sukoco, T.A. and Rozaki, Z. 2016. Remote sensing for estimating agricultural land use change as the impact of climate change. *Proceeding SPIE 9877, Land Surface and Cryosphere Remote Sensing III*, 987720 (5 May 2016), doi: 10.1117/12.2223878

Prasetyo, B. and Suriadikarta, D. 2006. Characteristics, potential, and technology of ultisol soil management for the development of dryland agriculture in Indonesia. *Jurnal Litbang Pertanian* 25: 39-46 (*in Indonesian*).

Primadani, P. 2008. Mapping of soil quality in several land uses in Jatipuro District, Karanganyar Regency (Bachelor Thesis). Universitas Sebelas Maret, (*in Indonesian*).

Purwanto. 2009. *Soil Biology Study of Environmentally Friendly Soil Management*. Indonesia Cerdas Press, Yogyakarta, (*in Indonesian*).

Reeves, D.W. 1997. The role of soil organic matter in maintaining soil quality in continuous cropping systems. *Soil and Tillage Research* 43: 131-167, doi: 10.1016/S0167-1987(97)00038-X.

Reijntjes, C., Haverkort, B. and Waters-Bayer, A. 1999. *Agriculture of the Future: An Introduction to Sustainable Low Input Agriculture*. Kanisius Press, Yogyakarta (*in Indonesian*).

Riptanti, E.W., Masyhuri, M., Irham, I., Suryantini, A. and Mujiyo, M. 2018. The development of leading food commodities based on local wisdom in the food-insecure area in East Nusa Tenggara Province, Indonesia. *Applied Ecology and Environmental Research* 16: 7867-7882, doi: 10.15666/aeer/1606_78677882.

Sanchez, P.A. 2019. *Properties And Management of Soils in the Tropics*. Cambridge University Press. Cambridge, UK.

Seker, C., Özaytekin, H.H., Negis, H., Gumus, I., Dedeoglu, M., Atmaca, E. and Karaca, U. 2017. Identification of regional soil quality factors and indicators: A case study on an alluvial plain (central Turkey). *Solid Earth* 8: 583-595, doi: 10.5194/se-8-583-2017.

Setyawanti, A. 2014. Erosion Study Using USLE Method and Small Plots Method in Sub-Sub Watershed Teleng, Giriwoyo District, Wonogiri Regency, Central Java Province (Doctoral dissertation).). UPN Veteran Yogyakarta, (*in Indonesian*).

Shukla, M.K., Lal, R. and Ebinger, M. 2006. Determining soil quality indicators by factor analysis. *Soil and Tillage Research* 87: 194-204, doi: 10.1016/j.still.2005.03.011.

Suntoro, S., Widijanto, H., Suryono, Syamsiyah, J., Afinda, D.W., Dimasyuri, N.R. and Triyas, V. 2018. Effect of cow manure and dolomite on nutrient uptake and growth of corn (*Zea mays* l.). *Bulgarian Journal of Agricultural Science* 24: 1020-1026.

Supriyadi, S., Purwanto, P., Sarijan, A., Mekiuw, Y., Ustiatik, R. and Prahesti, R.R. 2017. The assessment of soil quality at paddy fields in Merauke, Indonesia. *Bulgarian Journal of Agricultural Science*,23: 443-448.

Sutanto, R. 2005. Basics of Soil Science (Concepts and Reality). Kanisius Press, Yogyakarta, (*in Indonesian*).

Tematio, P., Tsafack, E.I. and Kengni, L. 2011. Effects of tillage, fallow and burning on selected properties and fertility status of Andosols in the Mounts Bambouto, West Cameroon. *Agricultural Sciences* 2: 334-340, doi: 10.4236/as.2011.23044.

Wander, M.M., Walter, G.L., Nissen, T.M., Bollero, G.A., Andrews, S.S. and Cavanaugh, D.A. 2002. Soil quality: science and process. *Agronomy Journal* 94: 23-32, doi: 10.2134/agronj2002.2300.

Wibowo, H., Warna, R.N., Wulandari, P., Prakoso, T., Prasetyo, D., Airlangga, T A., Purwanto, B.H., Utami, S.N.H. and Handayani, S. 2019. Identification the availability of P in land planted with corn on volcanic, karst and acid soils in Indonesia. The UGM *Annual Scientific Conference Life Sciences 2016, KnE Life Sciences* 179-188, doi: 10.18502/kls.v4i11.3864

Wibowo, Y.S., Buchari, H., Arif, M.A.S. and Utomo, M. 2014. Effect of soil cultivation systems on alang-alang (*Imperata cylindrica*) land on carbon biomass of soil microorganisms (C-mic) planted with soybeans (*Glycine max* L.) of the second season. *Agrotek Tropika* 2: 149-154 (*in Indonesian*).

Winarso, S. 2005. *Soil Fertility: the Basis of Soil Health and Quality*. Gava Media Press Yogyakarta (*In Indonesian*).

Xiao, S., Zhang, W., Ye, Y., Zhao, J., and Wang, K. 2017. Soil aggregate mediates the impacts of land uses on organic carbon, total nitrogen, and microbial activity in a Karst ecosystem. *Scientific Reports* 7: 41402, doi: 10.1038/srep41402.

Zhou, Y., Pei, Z., Su, J., Zhang, J., Zheng, Y., Ni, J., Xiao, C. and Wang, R. 2012. Comparing soil organic carbon dynamics in perennial grasses and shrubs in a saline-alkaline arid region, northwestern China. *PLoS ONE* 7: e42927, doi: 10.1371/journal.pone.0042927.