Evaluation of the Sustainability in Land Use and Soil Management Practices on Selected Soils by Using Some Physico-Chemical Properties

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Abstract

This study was conducted to evaluate the effect of different land use and soil management practices on selected soil properties and to explore the appropriate soil quality indicator for these practices utilized in selected areas. Sixteen land use and soil management practices included eight from Aung Ban and other eight from Hlegu region. Among the land use and soil management practices in Aung Ban Soils, L2 (Potato-Potato) was found the most soil properties such as soil bulk density, soil porosity and soil pH, EC, the fastest rate of saturated hydraulic conductivity, the strongest in aggregate stability, C:N and the higher CEC were in optimum range. Among the land use and soil management practices in Hlegu Soils, L13 (Flower-Flower) was also found the most soil properties such as soil bulk density, soil porosity and soil pH, the fastest rate of saturated hydraulic conductivity, higher C:N and CEC were in optimum range. According to linear equation, determination of saturated hydraulic conductivity was the most appropriate soil quality indicator in terms of less time consuming, less expensive and easily measurable for both regions.

Keywords: land use, soil management practices, physico-chemical properties

Introduction

For long-term soil productivity, evaluating the sustainability in land use and soil management practices are important. Either negatively or positively, soil qualities are affected by land use which depends on the soil function what land use focuses on. So, soil quality indicators are universally used to evaluate the sustainability in land use and soil management practices Land use involves the management and modification of natural environment such as payments and semi-natural habitats including arable fields, pastures, and managed woods Changes in land use and soil management practices affect most soil morphological, physical, chemical and biological properties to the extent reflected in agricultural productivity. Soil is the upper part of earth and natural resource with essential ecological, economic and social functions. Soil crusts that are consist of mineral and organic solids, air and water in pore spaces. It is a major foundation for nearly land uses and most important component of sustainability agricultural of the land environment and forms the interface between geosphere, atmosphere, hydrosphere and biosphere. Therefore, assessment of soil quality indicators with respect to land use types, management practices and land slope classes are useful and primary indicator for sustainable agricultural land (Doran 2002).

Soil quality indicators (SQIs) can express the capacity of soil to function and it is most commonly measured in the laboratory by describing soil physical, chemical and biological properties that are required to characterize a particular soil functions as agents for soil functional qualities. But, most of these are time-consuming, expensive and also require large numbers of samples to quantify the spa-

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tial and temporal variability of an area. Thus, it is needed to find out methods that can be cheaply, rapidly and repetitively applied (Shepherd and Walsh 2000). The objectives of this study were to evaluate the influence of different land use and soil management practices on some selected soil properties and to explore the appropriate soil quality indicator for the selected land use and soil management practices utilized in selected areas.

Materials and Methods

Site description

The study sites were located at Aung Ban, Shan State and Hlegu, Yangon Region. The lowest daily minimum temperature recorded during the study was 12 and 24°C, while the recorded daily maximum temperature was 31 and 38.5°C in Aung Ban and Hlegu, respectively. Recorded rainfall was more than 2000 mm in all locations. These study sites were purposely selected because they have different land use and soil management practices.

Soil sampling and analysis

The experiment consisted of sixteen land use and soil management practices on two study areas (Aung Ban and Hlegu). Among these practices, eights from Aung Ban [Natural Forest (L1), Potato - Potato (L2), Rainfed Rice (L3), Corn-Corn (L4), Rice-Vegetable (L5), Flower- Flower (L6), Vegetables using Good Agriculture Practices (L7), and Vegetable using Chemical Fertilizer (L8)] and other eights from Hlegu [Plantation Forest (L9), Rainfed Rice (L10), Rice-Flower (L11), Watermelon - Flower (L12), Flower-Flower (L13), Rice-Rice (L14), Vegetable using OM (L15) and Vegetable using Chemical Fertilizer (L16)]. Composite soil samples including disturbed and undisturbed conditions from each practice were collected with four replications at the depth of 0–15 cm in March, 2015.

The collected soil cores were carefully packed not to lose soil moisture content. Before analyzing, all composite soil samples were air-dried at room temperature, and after that grounded by using mortar and pestle and sieved with 2 mm sieve.

The soil samples were analyzed for soil physical and chemical properties at the laboratory of the Department of Soil and Water Science, Yezin Agricultural University. Soil bulk density (BD) was determined with core method (Blake and Hartge 1986). Soil particle density (PD) was determined by using the pycnometer method (Blake and Hartge 1986). Total soil porosity (SP) was not measured directly but was calculated from the BD and PD (Brady and Weil 1996). Dry sieving method was used for all land use and soil management practices to analyze soil aggregate stability (SAS) (White 1993). Cation Exchange Capacity (CEC) was measured by Bascomd's method. Soil organic carbon was determined by the method of Walkley and Black (1934). The percentage of organic carbon (C_{org}) in a soil is multiplied by 1.724 to obtain the percentage of soil organic matter (SOM). Soil pH was measured in a 1:5 soil water solution by a pH meter. Soil electrical conductivity (EC) was measured with an EC meter (Schott Instruments D-55122, Mainz, Germany) on the extract of soil with water (1:5). Total nitrogen (N_t) was measure by Kjeldahl method. Soil total calcium carbonate was measured by using the method of Bashour and Sayegh (2007). Measurements of hydraulic conductivity (HC) of saturated soils were based on the direct application of Darcy's equation to a saturated soil column of uniform cross-sectional area. Soil texture was classified by pipette method (Gee and Bauder 1986).

Statistical analysis

All collected data were analyzed by using the statistical software program (SPSS version 17.0). Oneway ANOVA was constructed for two regions as RCB with four replications. All means were compared by using LSD at 5% level. To select the best soil quality indicator as soil properties correlation and factor analysis were carried out again.

Results and Discussion

Aung Ban Soils

The result of soil properties as affected by different land use and soil management practices in Aung Ban soils were shown in Table (1). Among all land use and soil management practices, soils were sandy in texture, ranging from sandy loam to various sand classes. Among them, the maximum sand

Table 1. Soil properties as affected by different land use and soil management practices in Aung Ban soils

Land Use and Soil Management Practices	CEC meq $100g^{-1}$	EC dS m^{-1}	HC cm day^{-1}	BD gcm^{-3}	SP %	SOM %	TN	C:N	Sand %	Silt %	Clay %	pH	SAS	$CaCO_3$ %	Texture Classes
L1	24	0.7	22.67	1.66	37	1.73	0.1	10.03	27.1	40.0	32.9	5.7	0.62	7.51	Clay Loam
L2	28.8	0.41	323.2	1.64	36	2.16	0.11	11.38	74.6	11.5	17.6	5.5	0.43	8.5	Sandy Loam
L3	9.7	0.24	44.7	1.73	31	0.94	0.07	8.1	73.1	9.3	13.9	5.8	0.09	9.49	Sandy Loam
L4	16.1	0.15	318.6	1.63	34	1.82	0.1	10.56	62.3	26.9	10.8	5.2	0.17	8.92	Sandy Loam
L5	10.8	0.25	80	1.68	31	1.29	0.09	8.3	69.7	22.6	10.7	5	0.21	5.52	Sandy Loam
L6	8.2	0.39	60.03	1.93	15	0.74	0.05	8.56	69.9	21.0	9.1	4.9	0.1	4.5	Sandy Loam
L7	11.4	0.25	134.1	1.67	36	1.5	0.08	10.88	75.5	9.4	15.1	4.6	0.3	4.49	Sandy Loam
L8	7.1	0.12	52.19	1.76	33	0.47	0.04	6.82	78.4	10.9	7.7	7.2	0.05	19.21	Sandy Loam
$LSD_{0.05}$	0.9	0.04	7.06	0.12	5.23	0.46	0.05	1.53	22.1	2.61	3.09	0.17	0.05	0.299	
CV%	4.21	7.6	4.01	4.69	11.2	22.7	23.2	16.7	24.1	9.36	14	2.04	15.6	2.5	

L1 = Natural Forest
L2 = Potato-Potato
L3 = Rainfed Rice
L4 = Corn-Corn
L5 = Rice-Vegetables
L6 = Flower-Flower
L7 = Vegetable Using GAP
L8 = Vegetable Using Chemical Fertilizer

content was observed in L8 and then followed by L7, L2 and L3. The coarse texture of soil is likely to be transported of finer particles into deep layer due to long term cultivation processes. The lower content of silt and clay could be due to the result of preferential removal by accelerated water erosion during the monsoon months. L2 and L4 were recorded the highest HC (K_{sat}) value because of the higher in HC associated with lower in BD that increases in SP %. L1 gave the lowest HC value because of higher clay content than sandy soil (Carsel and Parrish 1988). Under the USDA-NRCS (2016) guide, the ideal BD for plant growth is between 1.4 and 1.6 g cm^{-3} and BD values >1.69 g cm^{-3} affects root growth. In this study, L3, L6 and L8 that BD values greater than 1.69 g cm^{-3} due to continuous cultivation at the top plow layer. L1 was highest in SP % and followed by L2, L4 and L7 because they were rich in organic matter, well aggregated and more porous which have a low bulk density. The highest SAS value was observed in L1followed by L2 and L4 because of high in clay and SOM content.

Among the different land use and soil management practices, L2 was recorded as the highest CEC (28.8 meq $100g^{-1}$). This might be due to the highest amount of SOM content (2.16 %). The higher the CEC, the more clay or OM present in the soil. In this study, EC values of all soils were less than 1 dS m^{-1}. It meant that low in EC indicated the low amount of soluble salts in the soils. L2 (2.16%) gave the highest SOM content and it could be due to the farmer's practices. On the other hand, the lowest SOM content was observed in L8 (0.47%) because of the complete removal of crop residues, usage of only chemical fertilizer and zero rotation in land management practice. The highest C:N 11:38 was observed in L2 among all land use and soil management practices. According to USDA-NRCS (2016), maintaining C:N in soils as >10:1 was the best for microbial decomposition and it upgrades the nutrient availability to plants. A pH range from 5.5 to 7.0 is suitable for most vegetable crops and development. In the table, the soil of L5 and L6 were in strongly acidic condition it could be due to the depletion of basic cations by leaching through the effect of climate condition in the area by crop removal. The highest content of total $CaCO_3$ was observed in L8 it could be due to addition of lime by farmer in this land use.

Selecting the Important Soil Properties (SP) and the Best Soil Quality Indicator (SQ) by using Linear Equations was as follows:

SP = 60.29 F_1+ 51.49 F_2+ 11.37 F_3………………………eq^n. (1)

According to equation (1), factor-1 contributed the maximum proportion, factor-2 showed the second proportion and Factor-3 contributed the lowest proportion. Therefore, it can be recognized that soil permeability parameter including minimum data set of SP, HC and $CaCO_3$ should be considered to analyze for Aung Ban.

SQ = -0.433 *SP* + 0.895 *HC* + 0.103 $CaCO_3$ ………………eq^n. (2)

According to equation (2), determination of hydraulic conductivity showing the maximum proportion of 0.895 could be the best soil quality indicator to describe the soil permeability condition of Aung Ban area. Similarly, Navin et al. (2010) discussed that determination of saturated water flow, hydraulic conductivity was more appropriate than the classification of soil texture in regards with soil hydraulics.

Hlegu Soils

Soil properties as affected by different land use and soil management practices in Hlegu soils were shown in Table (2). Soils of all land use and soil management practices were sandy loam in texture. L9 (1.6), L13 (1.59) and L15 (1.67) gave the optimum condition for plant growth in terms of soil bulk density (USDA–NRCS 2016). L10, L11, L15 and L16 were higher in BD and it could be due to continuous cultivation in the top plow layers and excessive biomass removal by harvesting. Higher results of SP were observed in L12 and L13. The rest of the plots were showed lower in SP as a result of soil compaction due to a decline of the soil organic carbon content in the upper soil horizon. The highest HC values were observed in L9 and L13 it could be due to higher in SP and lower in BD. The strongest SAS were observed in L9, L15 and L16 among the selected land use and soil management practices due to higher in SOM. The higher value of

Table 2. Soil properties as affected by different land use and soil management practices in Hlegu soils

Land Use and Soil Management Practices	CEC meq 100g-1	EC dS m^{-1}	HC cm day^{-1}	BD gcm^{-3}	SP %	SOM %	TN	C:N	Sand %	Silt %	Clay %	pH	SAS	$CaCO_3$ %	Texture Classes
L9	19	0.08	17.67	1.6	38	1.78	0.11	9.38	68.9	21.9	9.2	5.04	0.56	6.21	Loamy Sand
L10	12.8	0.18	0.61	1.8	28	0.87	0.05	10.09	83.5	8.2	8.8	7.88	0.21	9.43	Sandy Loam
L11	7.8	0.05	8.14	1.72	29	0.84	0.05	9.74	77.8	16.3	5.9	7.84	0.14	8.48	Loamy Sand
L12	15.8	0.13	13.48	1.69	32	1.2	0.07	9.94	78.2	15.6	6.2	7.49	0.45	8.98	Loamy Sand
L13	12.8	0.12	19.75	1.59	35	0.75	0.04	10.87	77.8	9.1	8.3	7.54	0.28	6.58	Sandy Loam
L14	7.9	0.14	12.43	1.75	29	0.26	0.02	7.54	82.3	10.0	7.7	7.68	0.06	6.99	Loamy Sand
L15	15.8	0.11	6.25	1.67	33	1.33	0.08	9.6	82.5	12.7	4.8	7.81	0.54	8.15	Loamy Sand
L16	23.9	0.69	8.95	1.7	29	1.92	0.11	10.12	81.1	10.1	13.1	7.66	0.57	8.03	Loamy Sand
$LSD_{0.05}$	0.55	0.032	1.64	0.17	7.99	0.27	0.02	1.74	3.96	1.67	1.97	0.22	0.04	0.27	
CV%	28.85	11.5	10.26	7.07	17.3	17.4	23.6	12.32	3.43	8.77	16.9	2.04	8.56	2.48	

L9 = Plantation Forest
L10 = Rainfed Rice
L311 = Rice - Flower
L12 = Watermelon – Flower
L13 = Flower - Flower
L14 = Rice - Rice
L15 = Vegetables Using OM only
L16 = Vegetables Using Chemical Fertilizer

CEC (meq $100g^{-1}$) was observed in L16 and it might be attributed to higher in organic matter and clay content. In contract, the lower was in L11 and L14 due to their low in clay content and OM. In the study, L9 was in acidic condition. This indicates that soil pH of forest lands are often more acidic than agricultural soils showing the effect of decomposition of soil OM and as a consequence, it releasing of organic acids leading to decrease in pH in forest soils value. EC of all soils affected by all land use and soil management practices were less than 1dS m^{-1}.

Highest SOM content (1.92%) was observed in L16 because of added organic matter yields creating a larger return of crop residues to the soil. The higher total nitrogen values were observed in L9 and L16 it could be due to higher in OM content in soil. The highest content of total $CaCO_3$ (9.43%). In some climate, soils that had high $CaCO_3$ content >5% in surface layer are not subjected to wind erosion (USDA-NRCS 2016).

Selecting the important soil properties and the best soil quality indicator by using linear equations was as follows:

SP = 56.47 F_1 + 28.35 F_2+22.07 F_3………………………eq^n. (1)

According to equation (1), factor-1 showed the maximum proportion, factor-2 placed at the second position and factor-3 contributed the lowest proportion. Therefore, it can be recognized that soil permeability parameter including minimum data set of HC, SOM and pH should be considered to analyze for Hlegu, Yangon region.

SQ = 0.8960 *HC* – 0.31 *SOM* + 0.322 pH………………eq^n. (2)

According to equation (2), determination of hydraulic conductivity showing the maximum proportion of 0.896 could be the best soil quality indicator to describe the soil permeability condition of Hlegu area, Yangon region.

Correlation analyses between soil parameters of Aung Ban soils were shown in Table (3). As correlation analyses are the first step to select the best soil quality indicator, it is necessary to perform showing the best correlation with each other. Cation exchange capacity was positive correlated with soil organic matter, total nitrogen, C:N and aggregate stability. Electrical conductivity was positively correlated with soil aggregate stability, clay and negative correlated with sand content. Saturated hydraulic conductivity was positively correlated with organic matter. Bulk density was negatively correlated with total porosity and negatively correlated with organic matter and total nitrogen. Soil organic matter was positively correlated with total N, C:N and aggregate stability. Total nitrogen was positively correlated with correlated with C:N and aggregate stability. Sand content was negatively correlated with silt, clay and aggregate stability. Clay content was positively correlated with aggregate stability. Soil pH was positive correlated with total $CaCO_3$. Then the highest positive correlation (+0.965) was found between soil organic matter and total nitrogen and highest negative correlation (-0.928) was found between bulk density and total porosity respectively.

Correlation between soil parameters of Hlegu soils were shown in Table (4). Cation exchange capacity was positive correlated with soil organic matter, total nitrogen, aggregate stability and clay. Electrical conductivity was positively correlated with clay. Saturated hydraulic conductivity was negatively correlated with bulk density, total $CaCO_3$ and positively correlated with total porosity. Bulk density was negatively correlated with total porosity and positively correlated with total $CaCO_3$. Total porosity was negative correlated with soil pH and sand. Soil organic matter was positive correlated with total nitrogen and aggregate stability. Total nitrogen was positive correlated with aggregate stability. Sand content was negative correlated with silt and positive correlated with soil pH. Silt content was negative correlated with soil pH. Then the highest positive correlation (+0.955) was found between soil organic matter Vs total nitrogen and highest negative correlation (-0.910) was found between bulk density Vs total porosity.

Conclusion

Among the land use and soil management practices in Aung Ban Soils, L2 (Potato-Potato) was found the most soil properties such as soil BD, SP

Table 3. Correlation between soil parameters of Aung Ban soils

Soil Parameters	CEC (meq $100g^{-1}$)	EC (dS m^{-1})	HC (cm day^{-1})	BD (gcm^{-3})	SP %	SOM %	TN %	C_{org}:N_t	Sand	Silt	Clay	pH	SAS	Total $CaCO_3$ %
CEC(meq $100g^{-1}$)	1													
EC(dS m^{-1})	0.633	1												
HC(cm day^{-1})	0.537	-0.218	1											
BD(g cm^{-3})	-0.592	-0.022	-0.509	1										
SP %	0.519	0.041	0.308	-0.928**	1									
SOM %	0.872**	0.392	0.711*	-0.760*	0.576	1								
TN %	0.826*	0.395	0.604	-0.800*	0.587	0.965**	1							
C:N	0.745*	0.359	0.700	-0.568	0.416	0.916**	0.800*	1						
Sand	-0.486	-0.791*	0.222	0.242	-0.235	-0.364	-0.427	-0.247	1					
Silt	0.357	0.629	-0.119	-0.139	0.030	0.313	0.393	0.173	-0.911**	1				
Clay	0.702*	0.876**	-0.134	-0.415	0.475	0.540	0.559	0.459	-0.852**	0.596	1			
pH	-0.094	-0.173	-0.250	0.044	0.222	-0.436	-0.425	-0.584	0.041	-0.150	-0.051	1		
SAS	0.845**	0.832*	0.130	-0.533	0.530	0.744*	0.725*	0.665	-0.723*	0.539	0.920**	-0.205	1	
Total $CaCO_3$	-0.168	-0.398	-0.079	-0.018	0.257	-0.414	-0.431	-0.531	0.203	-0.260	-0.235	0.961**	-0.336	1

Table 4. Correlation between soil parameters of Hlegu soils

Soil Parameters	CEC (meq $100g^{-1}$)	EC (dS m^{-1})	HC (cm day^{-1})	BD (gcm^{-3})	SP %	SOM %	TN %	C_{org}:N_t	Sand	Silt	Clay	pH	SAS	Total $CaCO_3$ %
CEC(meq $100g^{-1}$)	1													
EC(dS m^{-1})	0.491	1												
HC(cm day^{-1})	0.086	-0.189	1											
BD(g cm^{-3})	-0.353	0.148	-0.822*	1										
SP %	0.309	-0.360	0.732*	-0.910**	1									
SOM %	0.926**	0.520	0.037	-0.386	0.370	1								
TN %	0.905**	0.475	0.046	-0.384	0.396	0.995**	1							
C:N	0.382	0.182	0.024	-0.350	0.205	0.385	0.301	1						
Sand	-0.234	0.291	-0.682	0.705	-0.786*	-0.414	-0.451	-0.103	1					
Silt	0.159	-0.378	0.369	-0.450	0.590	0.442	0.503	-0.103	-0.849**	1				
Clay	0.625*	0.824*	0.073	-0.013	-0.100	0.462	0.432	0.166	-0.076	-0.225	1			
pH	-0.370	0.189	-0.546	0.584	-0.776*	-0.487	-0.543	0.093	0.903**	-0.769*	-0.208	1		
SAS	0.912**	0.393	0.149	-0.519	0.523	0.926**	0.921**	0.372	-0.348	0.383	0.268	-0.443	1	
Total $CaCO_3$	-0.066	0.124	-0.803*	0.718*	-0.681	-0.033	-0.070	0.238	0.585	-0.271	-0.204	0.619*	-0.091	1

and soil pH, EC, the fastest rate of HC, the strongest in SAS, C:N and the higher CEC were in optimum range. Among the land use and soil management practices in Hlegu Soils, L13 (Flower-Flower) was also found the most soil properties such as soil BD, SP and soil pH, the fastest rate of HC, higher C:N and CEC were in optimum range. According to linear equation, determination of saturated hydraulic conductivity was the most appropriate soil quality indicator in terms of less time consuming, less expensive and easily measurable for both regions.

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