RESEARCH ARTICLE

Assessment of soil quality index for agricultural purpose in agamsa sub-watershed, Ethiopia

Moges Tadesse Gedamu*

Gedamu MT. Assessment of soil quality index for agricultural purpose in agamsa sub-watershed, Ethiopia. AGBIR. 2021;37(2):102-107.

Assessment of soil quality has been recognized as an important step in understanding the effect of land management practices within agricultural lands. This study was designed to assess the quality soil based on some selected soil quality parametrs for agricultural purpose at Agamsa sub-watershed. Soil samples were collected from the 0-30 cm depth from eight locations in the study area. For the present study, SOC, electrical conductivity, available P, soil pH, total nitrogen, CEC, bulk density, soil separates (sand, silt, and clay), plant available water, exchangeable basic cations (Ca, Mg, and K), and DTPA extractable micronutrients (Fe, Mn, Cu, and Zn) were selected as potential soil quality indicators. A minimum dataset and linear scoring technique were used to evaluate the soil quality index. The PCA analysis identified total nitrogen, soil pH, DTPA-extractable Fe, available P, plant available water, bulk density, sand, and silt as an indicator for soil quality evaluation. The result of the study revealed that 25%, 37.5%, 12.5%, and 12.5% of the soil sampling unit was very high, high, moderate, and low in its quality index classes, respectively. Therefore, periodically assessing and maintaining soil quality will be indispensable for better yield and sustainable productivity in the study area.

Key Words: *Linear scoring function; MDS; Principal component analysis; Soil quality index.*

INTRODUCTION

The overall Ethiopian economy depends on smallholder agriculture and its sustainability is an important issue for the survival and well-being of the communities in the country [1]. Many of the issues of agricultural sustainability are related to the extent of maintaining soil quality attributes. Declining in soil quality has posed a tremendous challenge to increasing agricultural productivity, economic growth, and maintaining environment quality [2]. Therefore, a decision tool that can help to organize soil test information as well as interpret the effect of management practices on soils and ecosystems will improve the reliability and sustainability of management inputs [3]. Hence, the soil quality index is considered to be the most reliable and efficient decision tool that combines various soil information for multi-objective based decision-making. The soil quality index can help consultants, land managers, resource conservationists, and policymakers to identify the most viable management practices for sustaining land and yield quality [4]. It can be determined by assessing the various physical, chemical, and biological properties and processes of the soil [5] which are considered as indicators of soil quality [6]. A soil-quality indicator is a simple attribute of the soil that needs to be limited and convenient, simple, and easy to measure, economical, and be highly sensitive to environmental changes and soil management [7].

The determination of soil quality index (SQI) involves the selection of the minimum data set (MDS), score assignation for the selected indicators, and integration of the indicator scores into an overall index of soil quality [8]. The principal component analysis (PCA) method was used for selecting MDS [9], aimed at reducing the dimension of the large volume of data while minimizing the loss of information [10]. To solve the preconception caused by the use of different soil quality indicators expressed by different numerical scales, scoring functions are used to normalize data. The dimensionless quality indicators obtained from normalization were integrated into quality indices through additive, multiplicative, or weighed mean techniques [4]. The main objective of this study was to determine a soil quality through various physico-chemical soil quality indicators for agricultural purpose in Agamsa Sub-watershed, Ethiopia.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Agamsa sub-watershed, which is located in Habru District of Northeastern, Ethiopia (Figure 1). Geographically, the study area lies between 11°38'46"N and 11°39'38"N latitude; and 39°37'30"E and 39°39'43"E longitude, and at an altitude ranging from 1,575 to 1,870 meters above sea level. The total area of the watershed is about 408.12 ha. The study area is characterized by a bimodal rainfall pattern. The short (Belg) rain starts in February and ends in April while the main rainy (kiremt) season starts in June and ends in September with the erratic distribution. Its land use is mainly subsistence rain-fed agriculture and has a mean annual rainfall of 500-950 mm and a mean annual temperature of 14°C-31°C. According to the Ethiopian Mapping Agency, the study sub-watershed is covered by Pellic Vertisols, Eutric Cambisols, Regosols, and Eutric Lithosols. Pellic Vertisols is among the dominant soil type which covers about 68.4% of the study area [11].

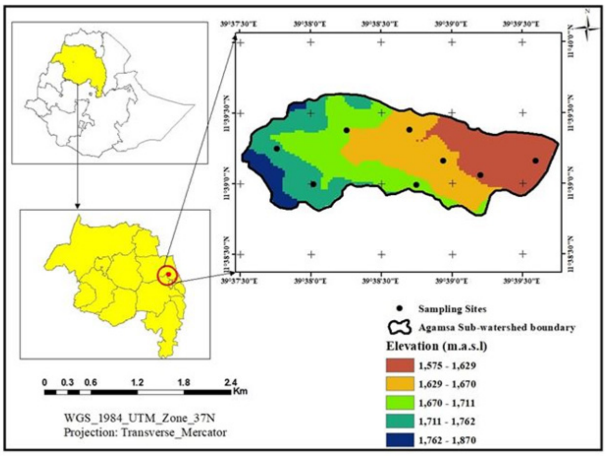

Figure 1) *Location map of the study area.*

Soil sampling and analysis

"Field data collection and soil sampling were carried out by considering the slope variation and fertility gradients of the study area. Besides, representative soil samples from a depth of 0 to 30 cm were collected from agricultural soils to examine the soil's physical and chemical properties. At each sampling site, a GPS (Global Position Systems, Garmin 76x model) reading was used in taking the coordinates. For each sampling site, a minimum of 10 to 15 subsamples was collected and composited within a 50 m distance between two sampling points using a random sampling technique. As a result, a total of eight composite soil samples were collected, by using Edelman auger at the

Department of Agriculture, The University of Swabi, Pak Department of Soil and Water Resource Management, Woldia University, P.O.Box 400, Ethiopia

Correspondence: *Moges Tadesse Gedamu, Department of Soil and Water Resource Management, Woldia University, P.O.Box 400, Ethiopia, E-mail: mogestadesse76@gmail.com*

Received: *February 23, 2021,* **Accepted:** *March 09, 2021,* **Published:** *March 16, 2021*

surface layer 0-30 cm. Then the collected soil samples were air-dried, gently crushed with mortar and pestle, mixed well, and passed through a 2-mm sieve. For the determination of total nitrogen (N) and organic carbon (OC), a 0.5-mm sieve was used. Then, approximately one kg of the composited fine soil sample was transported for analysis at Water Works Design and Supervision Enterprise, Addis Ababa, following the standard procedures (Table 1)".

Soil quality evaluation

Assessment of soil quality index (SQI) follows three essential steps, i.e., indicator selection, indicator transformation/scoring, and the combination of the indicators into one index value [8].

Indicator selection: It is difficult to analyze the various soil quality indicators to assess the quality of soil in the study area due to the expensive cost of its sampling and analysis. For the present study, soil organic carbon, electrical conductivity, available phosphorous, soil pH, total nitrogen, cation exchange capacity, bulk density, soil separates (sand, silt, and clay), plant available water, exchangeable basic cations (Ca, Mg, and K), and DTPA extractable micronutrients (Fe, Mn, Cu, and Zn) were selected. From these original untransformed soil indicators, principal component analysis (PCA), a multivariate statistical technique was applied to extract information and reduce data to choose the most important indicator in an MDS [12]. The PCs with eigenvalues more than >1 were selected. Within each chosen PC, the variables with the highest eigenvectors were taken in MDS. However, Pearson's correlation coefficient was used to reduce the redundancy of data for a retained variable within selected PCs. If the retained variable correlated, only the variable with the highest eigenvector was selected, and others were eliminated, while non-correlated relation each of it is considered as an important variable and chosen in MDS for calculating SQI.

Transformation of indicators (Scoring function): The second step is the transformation of each indicator and assigning it a score through a linear scoring method [10]. In the linear scoring method, each indicator is categorized as "more is better", "less is better", or "optimum is better". For "more is better", each observation is divided by the highest observed value so that this value received a score of 1, and the remaining received a score of <1. For "less is better" indicators, the lowest observed value is divided by each observation, so that the lowest value indicator received a score of 1, while others received a score of <1. For the "optimum is better, indicators observations are scored as more is better up to the threshold level and then scored as less is better" [13]. Two linear equations [Equation (1) and Equation (2)] were defined to transform each indicator into a common range between 0 and 1.

$$Y=(X-a)/(b-a) \qquad (1)$$

$$Z=(b-X)/(b-a) \qquad (2)$$

Where, Y and Z are the values of each variable after transformation; X is the value of the soil attributes to be transformed, and a and b are minimum and maximum values of each soil attributes. Equation (1) is for the "more is better" function, Equation (2) is for the "less is better" soil function, and the combination of both equations is used for the optimum function.

Soil quality indexing: After transforming/scoring, each retained indicator is then weighted based on PCA results. Each PC explained a certain proportion of variation in the data set; this proportion divided by the overall proportion explained by all the PCs with eigenvalues greater than 1 gives the weighted indicator to be allocated to each soil attributes under a particular PC. For each observation, the weighted indicators' scores were then summed up as per Equation (3) [4].

$$SQI=\sum_{i=1}^{n} Wi\ Si \quad (3)$$

Where, Wi is the weightage factor determined from the ratio of the total percentage of variance from each factor to the maximum cumulative variance coefficients of the PC considered; n is the number of indicators retained, and Si is the score of each parameter in the MDS. Then soil having a higher index score based on the ratings given in Table 2 indicates better soil quality and better performance of soil quality indicators.

Statistical analysis: All statistical analyses including mean, standard deviation, and coefficient of variation, PCA analyses, and determination of correlation coefficients were performed by the SPSS 20 for Windows.

TABLE 1

Standard procedures used to measure soil attributes for soil quality assessment as cited by Tadesse et al. (2020).

Attributes	Properties of soils	Applied standards for measurement
Physical	Soil texture (percentage of sand, Silt & Clay)	Bouyoucos hydrometer method (Bouyoucos, 1962)
	Bulk density, BD (g/cm^3)	Core method (Blake and Hartge, 1986)
	Plant available water, PAW (%)	Subtracting the FC value from the PWP value
Chemical	Acidity (pH-H$_2$O)	Digital pH meter (van Reeuwijk, 1986)
	Electrical conductivity, Ec (ds/m)	From the suspension prepared for pH analysis
	Soil organic carbon, SOC (%)	Walkley and Black, 1934
	Exch_Ca (cmolc/kg)	Atomic absorption spectrophotometer (Rowell, 1994)
	Exch_Mg (cmolc/kg)	Atomic absorption spectrophotometer (Rowell, 1994)
	Exch_K (cmolc/kg)	Flame photometer (Rowell, 1994)
	Cation Exchange Capacity, CEC (cmolc/kg)	Ammonium acetate extraction method (Chapman, 1965)
	Total nitrogen, TN (%)	Kjeldahl method (Bremner and Mulvaney, 1982)
	Available phosphorous, Av.P (mg/kg)	Olsen method (Olsen, 1954)
	Extractable Fe (mg/kg)	Extracted with diethylene triamine pentaacetic acid (DTPA) and then determined by atomic absorption spectrophotometer (Okalebo et al., 2002)
	Extractable Mn (mg/kg)	
	Extractable Cu (mg/kg)	
	Extractable Zn (mg/kg)	

TABLE 2

Classification criteria for the soil quality indices in the study area.

Indicators	Soil quality Level				
	Level 1	Level 2	Level 3	Level 4	Level 5
	Very high	High	Moderate	Low	Very low
Soil Quality Index (SQI)	>0.80	0.60 – 0.80	0.40 – 0.60	0.20 – 0.40	<0.20

RESULTS AND DISCUSSION

Soil quality physical indicators

The results of the study revealed that there were no textural differences within the soils of each sampling unit in the study area. Accordingly, all sampling units had clay loam textural class with a mean percentage value of 33.50, 31.75, and 34.75, for sand, silt, and clay, respectively. Similarly, the minimum value of sand, silt, and clay contents of the soil samples was 31%, 27.5%, and 32.5%, while the maximum contents were 37.5%, 35%, and 37.5%, respectively (Table 3). Moreover, the lowest (1.22 g cm^{-3}) and the highest (1.37 g cm^{-3}) bulk density values were recorded in the study area (Table 3). Since the acceptable range of bulk density is 1.3 to 1.4 g cm^{-3} for mineral agricultural soils [14], the soil bulk density obtained in the study was within the optimum range. Because of this, the soils in the study area were not too compact to limit root penetration and restrict the movement of water and air. The PAW values in the study area also were ranged between 13.19% and 17.08% (Table 3). Knowledge of PAW is important for various purposes such as irrigation scheduling and management. As cited by Teferi and Heluf [15], Beernaert and Bitondo [16], rated available water contents as very low, low, medium, high, and as very high when the value is <8, 8-12, 12-19, 19-21, and >21%, respectively. Based on this, the PAW of the soils in the study area was medium. This could be ascribed to its relatively high clay content and low to medium organic matter content. This is inline with Minasny and McBratney [17], who stated that a 1% increase in soil OC on average increased available water capacity by 1.16%, volumetrically.

TABLE 3

Descriptive statistics for all soil quality indicators in the studied locations.

Indicators	Minimum	Maximum	Mean	Std. deviation
pH	6.130	6.710	6.346	0.230
AP	2.500	9.650	4.918	2.914
SOC	0.490	2.150	1.021	0.600
TN	0.060	0.700	0.208	0.209
EC	0.060	0.100	0.075	0.015
Exch_Ca	20.380	29.300	24.115	3.055
Exch_Mg	8.920	12.080	10.686	1.251
Exch_K	0.290	0.590	0.403	0.096
CEC	36.900	53.100	43.825	5.944
Sand	31.000	37.500	33.500	2.171
Silt	27.500	35.000	31.750	2.390
Clay	32.500	37.500	34.750	1.927
BD	1.220	1.370	1.291	0.054
PAW	13.190	17.080	15.795	1.342
Fe	7.870	16.550	12.861	2.951
Mn	5.620	15.400	7.893	3.292
Cu	1.660	4.120	2.500	0.743
Zn	0.700	5.700	2.816	1.717

Soil chemical indicators

The minimum and maximum values of soil pH (pH_H$_2$O) in the study area were 6.13 and 6.71, respectively (Table 3). As per the pH ratings suggested by Karltun [18], the soil samples in the study area were rated as moderately acidic for values ranged from 5.6-6.5 and neutral for values ranged from 6.6-7.3. Thus, the pH values of soils of the study area are most suitable for plant growth and the availability of most plant nutrients might not be affected by these pH ranges. On the other hand, the total soluble salt contents expressed as EC is an important indicator of soil quality. It affects crop yields, crop suitability, plant nutrient availability, and activity of soil microorganisms which influence key soil processes [19]. The value of EC in the study area was varied from 0.06 to 0.10 ds m^{-1} with the mean value of 0.075 ds m^{-1} (Table 3). According to Landon [20], all soils in the study area did not have a salinity problem since the EC values were <2.0 ds m^{-1}.

The TN content was varied from 0.06% to 0.7% with a mean value of 0.208% (Table 3). According to Tadesse [21], the TN content in the study area was ranged from low to high. The low content of TN might have resulted from a low level of soil OM content, low application of N rich organic materials, and mineralization of the existing soil OM following cultivation. This is in line with the findings of Nigussie and Kissi [22], Belachew and Abera [23], and Emiru and Gebrekidan [24]. Similarly, the AP content of the soils of the study area varied from 2.5 mg kg^{-1} to 9.65 mg kg^{-1} with a mean value of 5.34 mg kg^{-1} (Table 3). Based on the critical values established by Tadesse [21], for some agriculturally important Ethiopian soils, the amount of AP observed in the soils of the present study area remains too low. This is probably due to continuous uptake by crops, crop residue removal, and low inherent AP content of the parent material. In general, the existence of low contents of AP is a common characteristic of most of the soils in Ethiopia [24] which is similar to the AP content observed in the soils of the present study area. Moreover, the recorded CEC of the soils in the study area ranged from 36.90 to 53.10 cmolc kg^{-1} with a mean value of 43.825 cmolc kg^{-1} (Table 3). Based on the ratings of Hazelton and Murphy (2016), all soils in the study area were rated as high (25-40 cmolc kg^{-1}) to very high (>40 Cmolc kg^{-1}) in its CEC values which might be due to the high specific surface area of the clay particles.

Exch-Ca followed by exch-Mg were relatively predominant cations on the exchange sites of soil colloidal materials over the exch-K in the order of Ca>Mg>K. The highest and the lowest values of exch-Ca were 29.3 and 20.38 cmolc kg^{-1} with a mean value of 24.115 cmolc kg^{-1}, respectively (Table 3). In line with soil fertility, a critical concentration of 0.2 cmolc kg^{-1} exch-Ca is required for tropical soils [20]. The results of this study indicate that soils under all sampling units had more Ca concentrations than the critical level. This implies that exch-Ca is not a limiting factor in the soils of the study area and the soils under the study area would not require an application of Ca fertilizer as an external input. The highest and the lowest values of exch-Mg were 12.08 and 8.92 cmolc kg^{-1} with a mean value of 10.686 cmolc kg^{-1} (Table 3). Since the concentrations of exch-Mg in all the land units of the study area were higher than the critical level of 0.5 cmolc kg^{-1} which is recommended for tropical soils [18], the responses for the addition of Mg as an external input in the form of fertilizer is unlikely in soils of the present study area. The highest and lowest values of exch-K were 0.59 and 0.29 cmolc kg^{-1}, respectively with a mean value of 0.403 cmolc kg^{-1} (Table 3). All investigated soils under all the sampling units of the study area had higher exch-K than the critical level (0.2 cmolc kg^{-1}) suggested by [20]. Hence, returns from K inputs application for crop production under this study area are less likely and its application in the form of fertilizer is not required.

The content of micronutrients in the studied area were in the order of Fe>Mn>Cu>Zn (Table 3). The values of available Mn vary from 5.62-15.40 mg kg^{-1} with a mean value of 7.893 mg kg^{-1} (Table 3). Hence, the value of available Mn is within the adequate range for most of the crops; since the threshold level is 1 to 48 mg kg^{-1}, and toxicity of Mn exists only when its value exceeds 48 mg kg^{-1} [25]. DTPA extractable Fe in the soil samples varied from 7.87 mg kg^{-1} to 16.55 mg kg^{-1} with a mean value of 12.861 mg kg^{-1}. Based on the critical limit of 4.5 mg kg^{-1} [26], all soil samples have sufficient available iron, and iron deficiency is unlikely for any crop grown on these soils. Moreover, the value of extractable Fe is within the adequate range for most of the crops; since the threshold level of soil DTPA extractable Fe is 4.5 to 20 mg kg^{-1}, and toxicity of Fe exists only when its value exceeds 20 mg kg^{-1} [25]. The result is following the previous studies in Ethiopia indicating that Fe deficiencies are not common [22-35]. Available Cu content, on the other hand, varied from 1.66 mg kg^{-1} to 4.12 mg kg^{-1} with a mean value of 2.50 mg kg^{-1}. Since the critical limit of Cu is 0.6 mg kg^{-1} [26], Cu deficiency is unlikely in the study area for growing any types of crops. Moreover, the extractable Zn in soils varied considerably and ranged from 0.7 to 5.7 mg kg^{-1} in the study area. The mean value of 2.816 mg kg^{-1} of the available Zn was more than the critical limit of Zn (0.6 to 1 mg kg^{-1}) as suggested by Lindsay, et al. [26].

Principal component analysis and selection of minimum data set attributes

The relationships between the eigenvalues and principal components (PC) are clearly shown in Figure 2. With an increase in PC, there is a corresponding decrease in eigenvalue. The PCA and communalities to evaluate SQI are given in Table 4. The four PCs with eigenvalue >1 among the soil attributes cumulatively explained 88.8% of the variance (Table 4). The eigenvalue decreased under PC 1 to PC 4. Similarly, variance explained decreased under PC1 to PC4.

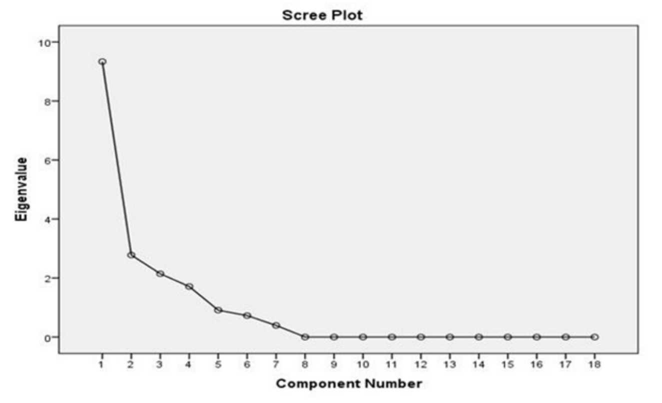

Figure 2) *Relationship between eigenvalue and a principal component.*

Under each PC, the variables with high eigenvector values were retained for MDS. After that, the highly weighted values for PC1 were AP, SOC, TN, exch_Mg, exch_K, Cu, and Mn. For PC2 sand and silt were highly weighted. While PC3 was represented by BD and Fe. Under PC4, PAW and pH were highly weighted. Then, the selected soil quality indicators from each PCs in the MDS were subjected to Pearson's correlation coefficient test. When retained variables correlated, only the highest eigenvector weight selected and others that were eliminated while the non-correlated indicator for each PC was considered as important and retained for MDS. Thus, results in Table 7 show a highly significant correlation ($P \leq 0.01$) between AP and each of Mn, SOC, and exch_K, while a significant correlation ($P<0.05$) between each of Cu and exch_Mg in PC1. Meanwhile, no significant correlation was found between AP and TN in PC1, Sand and silt in PC2, BD and Fe in PC3, and PAW and pH in PC4. So, in these PCs both TN and AP were retained in PC1, sand, and silt in PC2, BD, and Fe in PC3, and AWH and pH in PC4. Therefore, the obtained quality index method is influenced by AP=TN >sand=silt>BD=Fe>PAW=pH, and will be used in SQI calculation.

The "more is better" approach is followed by TN, AP, DTPA extractable Fe, and PAW, while the "less is better" approach is followed by sand and silt content of the soil and soil BD (Table 5). The score was then multiplied by the weighting factor derived from the PCA to get the ultimate index value for soil quality under different sampling units. The weighted factor of each PC based on the percent variance to the total variance ranged from 0.107 to 0.585. The weighted factor for the MDS then has the subsequent trend of PC1 (0.585)>PC2 (0.174)>PC3 (0.134)>PC4 (0.107) (Table 4).

TABLE 4

Results of the principal component analysis of the soil quality indicators.

	Principal components (PCs)				
	PC1	PC2	PC3	PC4	
Eigenvalues	9.335	2.778	2.145	1.712	
Variance Explained (%)	51.860	15.432	11.918	9.514	
Cumulative Variance (%)	51.860	67.293	79.211	88.725	
Weighted Factor	0.585	0.174	0.134	0.107	
Soil quality indicators	Factor Loadings	Communalities	1.717	1.717	1.717
pH	-0.563	-0.093	-0.261	0.652	0.819
AP	0.940	0.150	0.025	0.088	0.915
SOC	0.988	0.127	0.026	-0.026	0.993
TN	0.813	-0.423	-0.113	-0.006	0.853
EC	-0.686	-0.292	-0.077	0.348	0.684
Exch_Ca	0.786	-0.274	-0.466	-0.284	0.991
Exch_Mg	-0.869	-0.200	-0.142	0.212	0.859
Exch_K	0.931	0.028	-0.256	0.105	0.945
CEC	0.759	0.432	-0.026	0.221	0.811
Sand	0.123	0.894	0.416	0.097	0.998
Silt	0.441	-0.833	0.105	0.016	0.900
Clay	-0.686	0.026	-0.598	-0.129	0.846
BD	-0.585	-0.094	0.609	0.154	0.746
PAW	-0.073	0.503	-0.310	0.648	0.774
Fe	0.151	-0.531	0.749	0.334	0.978
Mn	0.793	-0.291	-0.059	0.499	0.966
Cu	0.862	-0.091	-0.242	0.374	0.950
Zn	0.888	0.180	0.350	-0.048	0.946

Soil quality index

After determining the MDS indicators, each of the indicators was scored based on the performance of soil function (Table 6). Each indicator was then standardized to a value between 0 and 1 scoring functions [4]. Once transformed, the indicator for each observation was weighted by using PCA results. Each PC explained a certain percentage of variation in the total data set. This percentage, divided by the total percentage of variation explained by all PCs with eigenvectors greater than 1, provided the weighted factor for variables chosen under a given PC (Table 6). Then, the values were fed into the additive model, and an aggregate score indicating the state of soil quality was determined and the numerical value of soil quality (SQI) was obtained for each sampling site as seen in Table 6 and Figure 3.

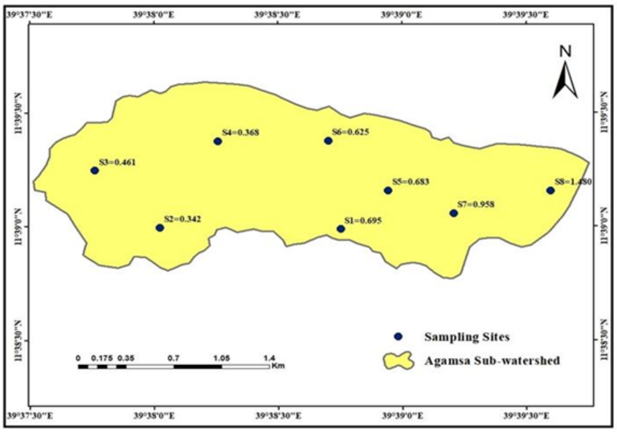

Figure 3) *Spatial distributions of soil quality index (SQI) in the study area.*

Therefore the result revealed that sampling unit/site 8 has the highest SQI (1.480) (Table 5 and Figure 3), probably due to its relatively level of slope gradient resulting in better accumulations of nutrients while the lowest SQI (0.342) was recorded from sampling unit/site 2 where the biomass production is low and leaching of nutrients due to steep slope. Based on the ratings of soil quality index given in Table 2 and the result of soil quality index recorded from the study area in Table 5, it was seen that 25% (S7 and S8), 37.5% (S1, S5 and S6), and 12.5% (S3) of the study area has very high, high, and moderate soil quality characteristics, respectively. The low-quality SQI class of the area suggesting that the area is highly sensitive to soil degradation.

TABLE 5

Scoring function and indicator values (xi) for each sampling site in the studied location.

Indicators	TN (%)	AP (mg/kg)	Sand (%)	Silt (%)	BD (g/cm³)	Fe (mg/kg)	PAW (%)	pH-H2O
Sampling point	Indicator value (Xi)	Xi	Xi	Xi	Xi	Xi	Xi	Xi
S1.	0.09	4.25	31.00	33.50	1.26	13.11	17.08	6.71
S2.	0.11	2.90	34.50	31.50	1.37	16.55	16.23	6.23
S3.	0.06	2.71	35.50	27.50	1.36	11.65	16.80	6.71
S4.	0.12	3.06	33.00	33.50	1.32	15.22	14.50	6.29
S5.	0.24	5.07	32.00	32.50	1.29	12.35	13.19	6.28
S6.	0.23	2.50	32.00	30.50	1.25	7.87	16.28	6.21
S7.	0.11	9.20	37.50	30.00	1.22	10.33	16.78	6.13
S8.	0.70	9.65	32.50	35.00	1.26	15.81	15.50	6.21
Minimum value	0.06	2.50	31.00	27.50	1.22	7.87	13.19	6.13
Maximum value	0.70	9.65	37.50	35.00	1.37	16.55	17.08	6.71
Scoring function	More is better	More is better	Less is better	Less is better	Less is better	More is better	More is better	More is better

TABLE 6

Parameters for scoring function and soil quality index..

Indicator	Total N	AP	Sand	Silt	BD	Fe	PAW	pH_ H_2O	SQI	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65
S/point	Score (Si)	Weight (Wi)	Si	Wi	Si	Wi	Si	Wi	Si	Wi	Si	Wi	Si	Wi	Si	Wi	$SQI=\sum^{n}_{i=1}(wi \times si)$
S1.	0.047	0.585	0.245	0.585	1.000	0.174	0.200	0.174	0.734	0.134	0.614	0.134	1.000	0.107	1.000	0.107	0.695
S2.	0.078	0.585	0.056	0.585	0.462	0.174	0.467	0.174	0.000	0.134	1.000	0.134	0.781	0.107	0.172	0.107	0.342
S3.	0.000	0.585	0.029	0.585	0.308	0.174	1.000	0.174	0.067	0.134	0.435	0.134	0.928	0.107	1.000	0.107	0.461
S4.	0.094	0.585	0.078	0.585	0.692	0.174	0.200	0.174	0.334	0.134	0.847	0.134	0.337	0.107	0.276	0.107	0.368
S5.	0.281	0.585	0.359	0.585	0.846	0.174	0.334	0.174	0.534	0.134	0.516	0.134	0.000	0.107	0.259	0.107	0.683
S6.	0.266	0.585	0.000	0.585	0.846	0.174	0.600	0.174	0.800	0.134	0.000	0.134	0.794	0.107	0.138	0.107	0.625
S7.	0.078	0.585	0.937	0.585	0.000	0.174	0.667	0.174	1.000	0.134	0.283	0.134	0.923	0.107	0.000	0.107	0.958
S8.	1.000	0.585	1.000	0.585	0.769	0.174	0.000	0.174	0.734	0.134	0.915	0.134	0.594	0.107	0.138	0.107	1.480
9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65	9.65

TABLE 7

Correlation matrix for highly weighted variables with high factor loadings.

Indicators	pH	AP	SOC	TN	EC	Exch_ Ca	Exch_ Mg	Exch_K	CEC	Sand	Silt	Clay	BD	PAW	Fe	Mn	Cu	Zn
Ph	1																	
AP	-0.418	1																
SOC	-0.622	0.931**	1															
TN	-0.39	0.616	0.756*	1														
EC	0.496	-0.671	-0.687	-0.474	1													
Exch_Ca	-0.469	0.646	0.735*	0.837**	-0.564	1												
Exch_Mg	0.728*	-0.784*	-0.887**	-0.602	0.838**	-0.639	1											
Exch_K	-0.431	0.839**	0.914**	0.789*	-0.643	0.826*	-0.842**	1										
CEC	-0.317	0.816*	0.815*	0.466	-0.41	0.408	-0.54	0.661	1									
Sand	-0.199	0.27	0.246	-0.321	-0.326	-0.372	-0.307	0.034	0.511	1								
Silt	-0.24	0.338	0.335	0.588	0.04	0.495	-0.224	0.35	-0.024	-0.647	1							
Clay	0.522	-0.724*	-0.693	-0.369	0.319	-0.195	0.624	-0.473	-0.546	-0.324	-0.512	1						
BD	0.325	-0.631	-0.58	-0.329	0.271	-0.715*	0.423	-0.639	-0.508	0.109	-0.268	0.209	1					
PAW	0.366	-0.011	-0.026	-0.277	0.147	-0.23	-0.015	0.192	0.156	0.358	-0.429	0.13	-0.102	1				
Fe	-0.011	0.096	0.088	0.267	0.047	-0.169	-0.114	0.001	-0.123	-0.119	0.58	-0.585	0.503	-0.245	1			
Mn	-0.069	0.714*	0.727*	0.808*	-0.362	0.605	-0.569	0.833*	0.528	-0.145	0.555	-0.526	-0.321	0.177	0.422	1		
Cu	-0.129	0.830*	0.826*	0.809*	-0.402	0.710*	-0.546	0.862**	0.784*	-0.03	0.401	-0.463	-0.553	0.11	0.1	0.898**	1	
Zn	-0.581	0.885**	0.909**	0.644	-0.707*	0.501	-0.794*	0.695	0.808*	0.42	0.242	-0.774*	-0.303	-0.222	0.263	0.594	0.698	1

Correlation is significant at the 0.05 level (2-tailed) and ** correlation is significant ant the 0.01level (2-tailed)

CONCLUSION

Soil quality assessment, which is multidimensional and influences development processes, is the primary practice employed for sustainable soil management. The final output of this study is assumed to be helpful in management decisions and it will assist land managers and land-use planners to know the current nutrient status of the soil to provide the basis for future strategies; to indicate the ameliorants required to correct nutrient imbalances, and to develop appropriate farm management aimed at productivity targets through more cost-effective nutrient decisions. According to this study, which sought to diagnose soil quality, it was seen that 25%, 37.5%, and 12.5% of Agamsa sub-watershed have very high, high, and moderate soil quality characteristics, respectively. Meanwhile, the low-quality SQI class covers 12.5% of the area, suggesting that the area is highly sensitive to soil degradation. Therefore, monitoring and periodically soil quality assessment and maintaining/enhancing soil fertility status will be indispensable for better yield and sustainable productivity through the employment of optimum management practices in the study area.

REFERENCES

1. Gelaw AM, Singh BR, Lal R, et al. Soil quality indices for evaluating smallholder agricultural land uses in northern Ethiopia. J Sustain. 2015;7(3):2322-37.
2. Girmay G, Singh B, Mitiku H, et al. Carbon stocks in Ethiopian soils in relation to land use and soil management. Land Degrad Dev. 2008;19:351-67.
3. Beinat E, Nijkamp P. Land-use management and the path towards sustainability. Multicriteria analysis for land-use management. Springer. 1998.
4. Andrews SS, Karlen D, Mitchell J, et al. A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agri Ecosys Env. 2002;90(1):25-45.
5. Feleke TG, Sharma PD, Selfeko D, et al. Assessing soil quality of abargay rangeland in farta district, Amhara Regional State, Ethiopia. J Soil Sci Env Mgmt. 2019;10(3):46-57.
6. Vasu D, Singh SK, Ray SK, Duraisami, et al. Soil quality index (SQI) as a tool to evaluate crop productivity in semi-arid Deccan plateau, India. Geoderma. 2016;282:70-79.
7. Zornoza R, Acosta J, Bastida F, et al. Identification of sensitive indicators to assess the interrelationship between soil quality, management practices and human health. Soil. 2015;1(1):173.
8. Volchko Y, Norrman J, Rosén L, et al. Using soil function evaluation in multi-criteria decision analysis for sustainability appraisal of remediation alternatives. Sci Total Env. 2014;485:785-791.
9. Andrews SS, Carroll C. Designing a soil quality assessment tool for sustainable agroecosystem management. Ecol App. 2001;11(6):1573-85.
10. Armenise E, Redmile-Gordon M, Stellacci A, et al. Developing a soil quality index to compare soil fitness for agricultural use under different managements in the mediterranean environment. J Soil Tillage Res. 2013;130:91-8.
11. Moges T, Ajanaw N. Land suitability evaluation for sorghum crop by using GIS and AHP techniques in Agamsa sub-watershed, Ethiopia. Cogent Food Agri. 2020;6(1):1743624.
12. Mukherjee A, Lal R. Comparison of soil quality index using three methods. PloS one. 2014;9(8):105981.
13. Singh A, Bordoloi L, Kumar M, et al. Land use impact on soil quality in eastern himalayan region of India. Env Monitoring Ass. 2014;186(4):2013-24.
14. Bohn H, Myer RA, O'connor GA, et al. Soil chemistry. John Wiley & Sons. 2002.
15. Teferi TW, Heluf G. Soil fertility assessment and mapping in selected highland areas of kuyu district in north shoa zone of Oromia Region. Haramaya University. 2008.
16. Beernaert F, Bitondo D. Simple and practical methods to evaluate analytical data of soil profiles. Maputo, Mozambique. 1990;25:145-150.
17. Minasny B, McBratney AB. Limited effect of organic matter on soil available water capacity. Eu J Soil Sci. 2018;69(1):39-47.
18. Karltun E, Mamo B, Gameda T, et al. Ethiopian soil information system towards improved fertilizer recommendations in Ethiopia. Nutrient indices for categorization of fertilizer blends from ethiosis district soil inventory data discussion paper. 2013.
19. Hazelton P, Murphy B. Interpreting soil test results: What do all the numbers mean?. CSIRO publishing. 2016.
20. Landon J. Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics.(eds.) John Wiley & Sons Inc. J. N. Y. 1991.
21. Tadesse T, Haque I, Aduayi E, et al. Soil, plant, water, fertilizer, animal manure and compost analysis manual. 1991.
22. Nigussie A, Kissi E. Physicochemical characterization of nitisol in southwestern Ethiopia and its fertilizer recommendation using NuMaSS. Glob Adv Res J Agri Sci. 2012;1(4):66-73.
23. Belachew T, Abera Y. Assessment of soil fertility status with depth in wheat growing highlands of Southeast Ethiopia. World J Agri Sci. 2010;6(5):525-31.
24. Emiru N, Gebrekidan H. Effect of land use changes and soil depth on soil organic matter, total nitrogen and available phosphorus contents of soils in senbat watershed, Western Ethiopia. ARPN J Agri Biol Sci. 2013;8(3):206-2012.
25. Lindsay W, Norvell W. Development of a DTPA micronutrient soil test. Agron. Abstr. 1969;12:1-11.
26. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Sci Soc Am J. 1978;42(3):421-28.
27. Abate K, Mohammed M, Kibret K, et al. Soil fertility assessment and mapping of spatial variability at amareganda-abajarso sub-watershed, north-eastern Ethiopia. East Af J Sci. 2016;10(1):1-14.
28. Aytenew M, Kibret K. Assessment of soil fertility status at dawja watershed in enebse sar midir district, Northwestern Ethiopia. Int J Plant Soil Sci. 2016;11:1-13.
29. Awasthi KD. Land use change effects on soil degradation, carbon and nutrient stocks and greenhouse gas emission in mountain watersheds. 2015.
30. Bouyoucos GJ. Hydrometer method improved for making particle size analyses of soils 1. Agro J. 1962;54:464-5.
31. Bremner JM, Mulvaney C. Nitrogen—total 1. Methods of soil analysis. Part 2. Chemical and microbiological properties. 1982;13:595-624.
32. Chapman H. Cation-exchange capacity 1. Methods of soil analysis. Part 2. Chemical and microbiological properties. 1965;15:891-901.
33. Glover J, Reganold J, Andrews P, et al. Systematic method for rating soil quality of conventional, organic, and integrated apple orchards in Washington State. Agri Ecosys Env. 2000;80(1-2):29-45.
34. Olsen SR. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Dep Agri. 1954.
35. Van Reeuwijk LP. Procedures for soil analysis. 1986.