Research Article
Open Access CrossMark

Soil fertility characterization in vertisols of southern Tigray, Ethiopia

Abstract

A fresh soil profile pit was opened and representative soil samples were collected from the profile and surface (0-15cm) soil of the experimental area to characterize the fertility status of the soils of the study area on the base of selected physicochemical properties. The soil textural class of the surface layer (0-25cm) of the profile and the mean composite surface (0-15cm) soil samples of the experimental field was clay loam while it was clay for the subsurface (25-150+cm) layers of the profile. The bulk density values of the layers in the profile varied consistently with depth ranging from 1.18g cm-3 at the surface layer to 1.32g cm-3 at the bottom layer while the average bulk densities of experimental field. The bulk and particle density values increased consistently with depth of the profile ranging from 1.18 to 1.32 and 2.51 to 2.85g cm-3, respectively. The organic matter (0.05 to 4.39%), available P (0.86 to 22.50mg kg-1) and total N (0.03 to 0.23%) of the soil profile decreased consistently with depth. Both the profile and the composite surface soil sample indicated that the soil of the site was slightly acidic to moderately alkaline in reaction (6.5 to 8.20). The soil exchange complex was mainly dominated by Ca and mg where the order of occurrence was Ca >mg>K>Na. The CEC values were very high ranging from 41.42 to 50.37c mol (+) kg-1. The results of the study revealed that the physical and chemical properties of the soils are highly variable to each other which disagrees the blanket rate of fertilizer recommendation throughout the country. The turning point to solve the problems should be restoring, maintaining and increasing the fertility status of the soils. These phenomena necessitate soil-crop specific fertilizer recommendation. Therefore, the existing soil fertility problems should be addressed sooner by introducing/developing resistant crop varieties, applying organic and inorganic fertilizers, and other soil fertility management options.

Keywords: soil profile, vertisols, soil fertility

Volume 2 Issue 1 - 2015

Okubay Giday,[1] Heluf Gibrekidan,[2] Tareke Berhe[3]

[1]Department of Soil Science, Wollo University, Ethiopia
[2]Department of Soil Sciences, Haramaya University, Ethiopia
[3]Department of Rice and Teff Research Advisor, Agriculture Transformation Agency, Ethiopia

Correspondence: Okubay Giday, Department of Soil Science, Wollo University, P.O Box 708 Addis Ababa, Ethiopia, Tel 0912730379, Email okubay_gidey1@yahoo.com

Received: August 04, 2014 | **Published:** January 09, 2015

Abbreviations: PBS, percent base saturation; BD, bulk density; PD, particle density; OM, organic matter; TP, total porosity; AP, available phosphorus; CEC, cation exchange capacity

Introduction

Declining soil fertility has continued to be a major constraint to food production in many parts of the tropical region. The low soil fertility in the tropics has been attributed to the low inherent soil fertility, loss of nutrients through erosion and crop harvests and little or no addition of external inputs in the form of organic or inorganic fertilizers.[1] This is particularly evident in the intensively cultivated areas, traditionally called high potential areas that are mainly concentrated in the highlands of Ethiopia. These imply that the outflow of nutrients in most smallholder farms far exceeds inflows.

To address the problems of soil fertility, several technological interventions, especially those geared towards nutrient management and soil moisture conservation, have been suggested.[1] Besides, the productivity of some soils is constrained by some other limiting factors even though they have high potential productivity or are naturally fertile. In this regard, Vertisols are important agricultural soils where primarily poor drainage and difficult workability limit nutrient availability and productivity, calling for proper soil fertility and water management practices.[2]

In Ethiopia, Vertisols are widely and intensively utilized soil types covering 11% or 12.7million hectares (ha) of the total land mass and is the fourth important major soil group.[3] More than half (8.6million ha) of the Vertisols are found in the central highlands with altitude of more than 1500 meters above sea level (masl). Generally, Vertisols have high montmorillonite clay known for its shrink-swell properties in response to changes in soil moisture content. Vertisols produce large cracks that are closed only after prolonged rewetting and thus become hard when dry and very sticky and plastic when wet. These soils are also characterized by the presence of gilgai micro-relief or subsoil showing slicken sides or spheroid structure due to contraction and expansion processes during drying and wetting.[4] Vertisols generally have weak horizon differentiation, low hydraulic conductivity, low infiltration rate and high moisture retention capacity ranging from 60 to 70% at field capacity because of their high clay content. The pH of Vertisols in some highland areas of the country varies from slightly acidic to strongly alkaline, of course depending on different factors.[5]

Many soils in the highlands of Ethiopia are inherently poor in available plant nutrients and organic matter (OM) content.[6,7] Tekalign et al.,[6] also reported that the Ethiopian highland Vertisols tend to exhibit low total nitrogen (N) and OM contents, and application of N fertilizer is considered essential to improve cereal crops production on these soils. However, cereal-dominated cropping systems, aimed at meeting farmers subsistence requirements, coupled with low usage of chemical fertilizers have led to a widespread depletion of soil nutrients in the major cereal crops growing regions of the country. Heavy rains during the part of the main cropping season (June to August) also cause substantial soil nutrient losses due to intense leaching and erosion on Nitisols and denitrification on the frequently water-logged Vertisols.[7]

Soil degradation and depletion of soil nutrients are among the major factors threatening sustainable cereal production in the Ethiopian highlands. However, although knowledge on soil fertility status plays a vital role in enhancing production and productivity of the agricultural sector on sustainable basis, little information is available in Southern parts of Tigray in general and the specific study area in particular. Therefore, this study was proposed to characterize the fertility status of the Vertisols in the study area based on selected soil physiochemical properties.

Materials and methods

General description of the study area

Ofla District, one of the six districts of the Southern Zone, is located about 620km north of Addis Ababa and about 150km south of Mekelle city. The study District has about 133, 296 ha of land area and the altitude vary between 1700 and 2800masl whilst the slope ranges from 2 to 35%.[8]

The study area is characterized by a bimodal rainfall pattern with the main wet season (*kiremt*) extending from July to September and the small wet season (*Belg*) which extends from March to May. The area is characterized by heavy and erratic rainfall distribution. The ten years (2002-2011) mean annual rainfall is 980.5 while the annual rainfall in 2011 was 1050mm. Similarly, the mean maximum and minimum temperatures were 22.28 and 7.69°C, respectively. Vertisols are the dominant soil types in the area. The area has crop-dominated mixed crop-livestock farming system. The dominant crops growing around the experimental area are wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), barley (*Hordeum vulgare*), teff (*Eragrostis tef*) and some species of legume crops.[8]

Soil sampling, sample preparation and analysis

Surface soil and profile sampling and sample preparation: A fresh soil profile pit with 1m width, 2m length and 1.5m depth was excavated at a point representative for the adjacent sites of A and B. The soil profile was described morphologically under field condition and sampled depth-wise (layers) for characterization of some selected physicochemical properties. Moreover, surface soil samples (0-15cm depth) were collected using Auger from eight to ten spots from each block to form one composite soil sample per block for soil fertility evaluation. Undisturbed (core) soil samples were also collected using core samplers for soil bulk density determination.

The composite surface soil and soil profile samples collected were air dried in wooden material, ground and sieved to pass through a 2mm sieve in preparation for laboratory analysis. Finally, the samples (surface and profile) were analyzed in the laboratory (National Soil Testing Center) for texture, particle density, bulk density and total porosity (physical properties), and for pH, OM, total N, available P, cation exchange capacity and exchangeable bases (Ca, Ma, K and Na) among the soil chemical properties.

Analysis of soil physical and chemical properties

Soil particle size distribution (texture) was analyzed by the Bouyoucos hydrometer method following the procedure described by Bouyoucos GJ.[9] Bulk density was determined from the undisturbed (core) soil samples collected using core samplers, weighed at field moisture content and then dried in an oven at 105°C.[10] Similarly, particle density was measured by the Pycnometer method. Finally, soil total porosity was estimated from the bulk density (BD) and particle density (PD) values as

$$\textit{Total porosity}\ (\%) = (1-BDPD)\times 100$$

Soil pH was measured potentiometrically using a pH meter with combined glass electrode in 1: 2.5 soils: water ratio suspension as described by Carter.[11] The Walkley et al.,[12] wet digestion method was used to determine soil organic carbon content and percent soil OM was obtained by multiplying percent soil organic carbon by a factor of 1.724. Similarly, total N was analyzed using the Kjeldahl digestion and distillation method as described Jackson,[13] by oxidizing the OM in concentrated sulfuric acid solution (0.1N H_2SO_4) and converting the nitrogen into NH_{4+} as ammonium sulfate. Determination of available P was carried out by the Olsen method using sodium bicarbonate as extracting solution.[14]

The exchangeable bases (Ca, Mg, K and Na) in the soil were determined from the leachate of 1 molar ammonium acetate (NH_4OAc) solution at pH 7.0. Exchangeable Ca andmg in the extract were measured by atomic absorption spectrophotometer whilst K and Na were read using flame photometer from the same extract.[15] Similarly, CEC was measured after leaching the ammonium acetate extracted soil samples with 10% NaCl solution and determining the amount of ammonium ion in the percolate by the Kjeldahl procedure and reported as CEC.[16]

Statistical analysis

Finally, the fertility status of the soil of the study area was evaluated based on the concentrations of the respective parameters (both physical and chemical properties) obtained from the laboratory analyses. In other words, the results of the soil analysis were compared with established ratings and/or critical levels or limits for different classes of the respective plant nutrient elements in evaluating the fertility status of the soils studied i.e. The analysis results of the soil samples was interpreted using descriptive statistics.

Results and discussion

Characterization of the soil of the study area

Physical properties of the soil

Texture: Apparently, particle size distribution has important bearing in soil water movement, aeration, root extension, oxidation-reduction processes and nutrient and OM contents as well as composition. In the present study, the texture of the surface layer (0-25cm) of the profile and the average of the composite surface (0-15cm) soil samples of site A and B were clay loam. However, the texture changed to clay in the subsurface layers of the soil profile opened adjacent to the experimental plots. Generally, the soil profile contained more than 30% clay throughout (>50% clay below the plow layer) and had intersecting slickenside's and cracks which open and close periodically suggesting the presence of Vertical horizon. The proportions of clay and silt within the profile ranged from 32 to 52% and from 23 to 35%, respectively, whereby the silt fraction and the silt to clay ratio decreased consistently with increasing soil depth (Table 1). On the other hand, the sand content at the surface layer of the soil profile was the highest (33%) followed by the bottom layer, which contained 27% sand.

Citation: Giday O, Gibrekidan H, Berhe T. Soil fertility characterization in vertisols of southern Tigray, Ethiopia. *Adv Plants Agric Res.* 2015;2(1):7–13. DOI: 10.15406/apar.2015.02.00034

The silt to clay ratio of the soil ranged from 0.46 to 1.09 for the profile and from 0.38 to 1.16 and 1.43 to 1.56 for the composite surface soil samples of site A and B, respectively. This ratio is one of the indices used to assess the rate of weathering and determine the relative stage of development of a given soil. According to Young,[17] a ratio of silt to clay below 0.15 is considered as low and indicative of an advanced stage of weathering and/or soil development while greater than 0.15 indicates that the soil is young containing easily weatherable minerals. Hence, the silt to clay ratio of the soil observed in the present study is generally high (greater than 0.15) both for the profile and the composite surface soils (Table 1) suggesting low degree of weathering and young soil development stage.

Particle and bulk density: The bulk density values of the layers in the profile varied consistently with depth ranging from 1.18g cm^{-3} at the surface layer to 1.32g cm^{-3} at the bottom layer while the average bulk densities of site A and B were 1.19 and 1.20g cm^{-3}, respectively. These values are closer to the average range of bulk density for mineral soils which is 1.30-1.40g cm <sup.-3<sup=""> as indicated by Bohn et al.[18] The relatively lower bulk density values observed at the surface layer could be due to the relatively high OM contents (Table 1) which resulted in high total porosity (>52%). On the other hand, the relatively high bulk density values in the layers below the plow depth (0-25) could be due to the rapid decline in OM content as well as reduced root penetration and compaction caused by the weight of the overlying soil material. </sup.-3<>

The particle density values of the layers in the profile increased consistently with depth ranging from 2.51gcm^{-3} at the surface (0-25cm) layer to 2.85gcm^{-3} at the bottom layer (98-150+cm) while the average particle density of site A and B were 2.52 and 2.53gcm^{-3}, respectively (Table 1). For many mineral soils, the particle density ranges from 2.60 to 2.70gcm^{-3} and it does not vary a great deal for different soils unless there is considerable variation in OM content and mineralogical composition of the soil.[19] Therefore, the particle densities of the soils where the current study was conducted are closer to the average range of particle density for mineral soils. However, the particle density values of the surface layers of the profile and the mean of the composite surface soil samples of site A and B were relatively lower than the underlying subsurface layers of the profile. This is probably attributed to the rapid decline in OM with increasing soil depth from 4.39% at the plow depth to 0.05% at the bottom of the subsoil (Table 2).

Total porosity: Total porosity of the soil profile decreased consistently with depth from 52.99% at the surface layer to 49.43% at the bottom layer. In accordance with the total porosity of the surface layer of the profile characterized representing both sites where the average volumes of total soil porosity of site A and B were 52.85 and 52.51%, respectively (Table 1). The relatively higher values of total porosity observed at the surface layer of the profile and the composite surface soil samples across site A and B correspond to the higher OM content and the resultant lower bulk density values (Tables 1) (Table 2). The range of total porosity observed in the soils considered in this study falls within the range of 46 to 64% reported by Abayneh[20] for the soils of the Raya valley.

Chemical properties of the soil

Soil reaction (pH): The data in Table 2 indicates that the soil pH value within the soil profile linearly increased with increasing profile depth. According to the soil pH rating established by Tekalign,[21] the results of soil analysis in this study showed that the pH of the soil profile varied from slightly acidic (pH=6.3) at the surface layer (0-25cm depth) to strongly alkaline (pH=8.2) at the bottom (98-150+cm) layer. Similarly, the mean pH values of the composite surface soil samples from site a (6.5) and site B (6.6) were categorized under the slightly acidic soil reaction class as per the same rating provided.

According to Eylachew,[5] the pH of Vertisols characterized in different parts of the country was within the range of 6.3 to 7.6 on the surface layer and within 6.8 to 8.5 in the underlying layers. Therefore, the soil pH values recorded for the profile and the composite surface soil samples of both sites of the present study fully agree with these findings. The increase in pH consistently with increasing soil profile depth may be due to the marked increase observed in the basic cations particularly exchangeable Ca andmg with depth (Table 2). The increase in basic cation concentrations with soil depth, in turn, may suggest the existence of downward movement of these constituents from the surface layer to the subsurface layers within the profile.

Organic matter: The organic matter (OM) content of the profile decreased consistently with depth ranging from 4.39% at the surface layer (0-25cm) to 0.05% at the bottom (98-150+cm) layer (Table 2). On the other hand, the composite surface soil samples collected from both sites had mean OM contents of 3.71 and 2.26%, respectively. According to the rating of soil OM content established by Tekalign,[22] the surface layer of the profile had medium while the composite surface soil samples of both sites had medium and low OM contents, respectively.

The reasons for the low to medium OM levels observed in the soils of the present study areas could be intensive cultivation of the land which encourages oxidation reaction and the total removal of crop residues for animal feed and source of energy. Moreover, there is no practice of organic fertilizers addition, such as animal (farmyard) manure and/or green manure that could have contributed to the soil OM pool in the study area. In other soils of Ethiopia, variability of soil OM has also been related to land use history and the associated management practices. Accordingly, OM content is generally low in cultivated soils than soils under grazing lands and in soils of grazing land soils compared to soils of forest land.[23] Moreover, medium OM content of 3.07 and 2.07% were reported for soil samples collected from the plow layer of cultivated lands from Gojjam and Amaressa areas, respectively.[3]

Total nitrogen: The total N contents of the soil profile varied from 0.03% at the bottom layer (98-150+cm) to 0.23% at the surface (0-25cm) layer (Table 2). The total N content of the surface layer of the profile (0.23%) and the mean total N contents of the composite surface soil samples of site a (0.17%) and site B (0.13%) of the study area are rated as medium based on its classification provided by Berhanu.[24] Apparently, the highest value of total N (0.23%) corresponds to the layer of the profile containing the highest OM content (4.39%) and the lowest amount of total N (0.03%) was recorded in the bottom layer which contained the lowest OM content (0.05%) (Table 2).

In line with the OM contents of the profile, the contents of the total N also decreased consistently with depth suggesting the strong correlation between the two soil parameters. The medium total N contents indicate that the soils of the study area are deficient in N to support proper growth and development of crops for expressing their genetic yield potential which suggest that the soils require fertilization with external N inputs and gradual build of its OM levels to ensure sustainable productivity.

Citation: Giday O, Gibrekidan H, Berhe T. Soil fertility characterization in vertisols of southern Tigray, Ethiopia. *Adv Plants Agric Res.* 2015;2(1):7–13. DOI: 10.15406/apar.2015.02.00034

Table 1 Selected physical properties of the profile and composite surface soil samples of the study area

Depth (cm)	Particle size (%)			Textural class	Silt/clay ratio	BD (g cm^{-3})	PD (g cm^{-3})	TP (%)
	Sand	Silt	Clay					
0–25	33	35	32	Clay loam	1.09	1.18	2.51	52.99
25–98	23	25	52	Clay	0.48	1.29	2.61	50.57
98–150^{+}	27	23	50	Clay	0.46	1.32	2.85	49.43
Composite surface (0-15) soil samples of site A								
Block 1	31	19	50	Clay	0.38	1.17	2.52	53.57
Block 2	31	37	32	Clay loam	1.16	1.16	2.46	52.85
Block 3	31	37	32	Clay loam	1.16	1.23	2.57	52.14
Mean	31	31	38	Clay loam	0.90	1.19	2.52	52.85
Composite surface (0-15) soil samples of site B								
Block 1	23	47	30	Clay loam	1.56	1.24	2.56	51.56
Block 2	27	43	30	Clay loam	1.43	1.19	2.50	52.40
Block 3	25	45	30	Clay loam	1.50	1.17	2.52	53.57
Mean	25	45	30	Clay loam	1.50	1.20	2.53	52.51

BD, bulk density; PD, particle density; TP, total porosity

Table 2 Selected chemical properties of the profile and composite surface samples of wheat and teff experimental area. OM, organic matter; AP, available phosphorus; CEC, cation exchange capacity; PBS, percentage base saturation

Depth (cm)	pH (H_2O)	OM (%)	Total N (%)	AP (mg kg^{-1})	Exchangeable bases and CEC (coml. (+) kg^{-1})					PBS
					Na	K	Mg	Ca	CEC	
0–25	6.3	4.39	0.23	20.50	0.26	0.73	9.14	29.14	41.42	94.81
25–98	7.5	0.10	0.06	2.20	0.43	0.42	10.99	35.44	50.37	93.87
98–150^{+}	8.2	0.05	0.03	0.86	0.76	0.51	11.48	31.89	49.33	90.49
Composite surface (0-15) soil samples of site A										
Block 1	6.6	3.56	0.16	22.30	0.20	0.58	10.80	22.14	40.19	83.90
Block 2	6.4	3.72	0.18	19.34	0.17	0.58	9.41	22.57	42.77	81.44
Block 3	6.4	3.86	0.17	21.78	0.22	0.58	11.78	21.00	41.44	81.03
Mean	6.5	3.71	0.17	21.14	0.19	0.58	10.66	21.90	41.47	82.12
Composite surface (0-15) soil samples of site B										
Block 1	6.6	2.20	0.19	13.68	0.18	0.57	10.00	22.00	41.20	79.49
Block 2	6.5	2.33	0.10	13.52	0.22	0.75	12.00	21.71	40.45	85.74
Block 3	6.6	2.24	0.10	15.80	0.19	0.59	11.00	22.54	42.80	80.19
Mean	6.6	2.26	0.13	14.33	0.19	0.64	11.00	22.08	41.48	81.81

Available soil phosphorus: The available P content of the profile ranged from 0.86mg kg^{-1} at the bottom layer to 20.50mg kg^{-1} at the surface layer. Similarly, the mean available P contents of the composite surface soil samples of site A and B were 21.14 and 14.33mg kg^{-1}, respectively (Table 2). According to Olsen et al.,[14] rating, the average available P contents of the composite surface soil samples of both sites and the surface layer of the profile fall under the high P status implying that response of crops to P fertilization at such P level may not be very high.

On the other hand, Tekalign et al.,[25] reported that 8.5mg P kg^{-1} of soil was the critical level for some crops such as faba bean on major and/or agriculturally important soils of Ethiopia when assessed by the Olsen P extraction method. Finck et al.,[26] also revealed that for cereals, the critical limit below which responses to applied P could be expected on Vertisols is about 8mg kg^{-1} soil of Olsen extractable P. Considering these critical levels of soil P, the amount of available P observed in the soils of the present study remains to be high.

The content of P showed a decreasing trend with soil depth (Table 2). This is in agreement with the findings of Tekalign et al.,[27] who reported that topsoil available P is usually greater than that in the subsoil due to sorption of the artificially added P on the soil surface and its gradual desorption, greater biological activity and higher addition and accumulation of organic materials on the surface soil than in the sub soils. Mulugeta[28] Also indicated a decrease in P content with increasing depth due to its fixation by clay and Ca in the subsurface soil which was found to increase with profile depth.

On the other hand, Mohammed et al.,[29] observed low levels of available P in the surface horizons of the cultivated soils of the Chercher highlands in Eastern Ethiopia. In general, existence of low contents of available P is a common characteristic of most of the soils in Ethiopia[25,30,31] which is contrary to the P content observed in the soils of the present study area.

Exchangeable bases: Exchangeable Ca followed bymg was the predominant cation in the exchange sites of both the profile and the composite surface soil colloidal materials (Table 2). The mean exchangeable Ca andmg contents of the composite surface soil samples of site A and B were 21.90 and 10.66 and 22.08 and 11.00c mol (+) kg^{-1} while that of exchangeable Na and K were 0.19 and 0.58 and 0.19 and 0.64c mol (+) kg^{-1}, respectively. Exchangeable Ca content varied from 29.14c mol (+) kg^{-1}) at the surface layer to 35.44c mol (+) kg^{-1} at the middle layer and did not show any clear pattern of variability among the layers of the profile, whereas exchangeablemg increased with soil depth consistently from 9.14c mol (+) kg^{-1} at the surface layer to 11.48c mol (+) kg^{-1}) at the bottom layer.

The high contents of exchangeable Ca andmg show that the soil parent material primarily rich in basic cations and the divalent cations are retained in higher concentrations and for longer periods by the soil colloidal particles because of their higher selectivity coefficient over the monovalent cations. A high content of these two cations has also been reported in Vertisols of Bichena and Woreta areas[30] and in soils of Jelo micro-catchment.[29] According to the rating of FAO,[32] the concentrations of these two cations are rated as very high where they saturated 88 to 92% of the soil exchange complex.

In the surface soil of study area, the proportions of the cations were in the order of Ca>mg>K>Na. This might be related to the parent material from which the soils have been developed i.e. basalt rock and their differential attraction to the soils' exchange complex which is approximately in that order. Generally, exchangeable Na and K contributed very small proportion to the CEC. Nevertheless, according to the FAO,[32] the observed exchangeable K value was high for the surface horizon where it generally decreases inconsistently with increasing soil profile depth (Table 2). This indicates that the potential supply of K for crop growth largely lies in the surface layer and hence calls for protection and maintenance of the surface soil to secure sustainable crop production without any external addition of K fertilizers. The content of exchangeable Na in the soil relative to the CEC was below the critical value to cause soil sodicity and, hence, Na toxicity on crops and/or adverse effect on soil physical properties are unlikely to occur. Yet, the content of exchangeable Na showed a consistent increase trend with soil depth from 0.26c mol (+) kg^{-1} at the plow depth to 0.76c mol (+) kg^{-1} at the bottom subsurface layers (Table 2).

Cation exchange capacity and percent base saturation (PBS): According to the rating suggested by landon,[33] the CEC values of the surface layer of soil profile fall under the very high rate. As indicated in Table 2, CEC did not show any clear pattern of variability among the layers of the profile although the surface layer had the lowest CEC (41.42)c mol (+) kg^{-1} while the highest (50.37c mol (+) kg^{-1}) was obtained at the upper subsoil layers of the profile. Similarly, the mean CEC values of the composite surface soil samples from site A and B were also rated as very high and was 41.47 and 41.48c mol (+) kg^{-1}, respectively (Table 2). Although the OM content of the soil is low to medium, the amount and type of clay might have been very important in contributing to the CEC values. The type of clay could most probably be montmorillonite with a shrinking and swelling behavior with extensive internal and external surfaces that can attract or adsorb many cations. This is in line with the findings of Mebit[34] who reported very high CEC on Eutric Vertisols and that varied with soil depth.

The CEC to clay ratios were over 0.97 reaching 1.29 in the surface horizon. Therefore, the range suggests the presence of 2:1 clay minerals and can be expected to have more nutrient reserves.[33] Mohammed et al.[29] Also indicated that the CEC to clay ratios of the soils of Jelo catchment were over 0.67 reaching 2.05 in some horizons which predicted the presence of smectite (montmorillonite) clay mineralogy of high inherent CEC in all of the soil horizons. This shows that inorganic material (colloidal clay) is the predominant contributing factor to the very high CEC observed in the soils. Moreover, the high CEC values imply that the soil has high buffering capacity against the induced changes.

According to the rating by Hazelton and Murphy,[35] the percent base saturation (PBS) of the surface layer of the soil profile was rated as very high. Similarly, the mean values of the composite surface soil sample of both sites were also very high ranging from 81.03 to 83.90 in site A and from 79.49 to 85.74% in site B (Table 2). Unlike CEC and some of the exchangeable cations (Mg and Na) which increased with soil depth, PBS decreased consistently with depth (Table 2).

Conclusion

A fresh soil profile pit was opened and described, and samples were collected depth-wise moreover, composite surface soil (0-15cm) samples were collected from site A and B to characterize the fertility status of the soils of the study area on the bases of selected physicochemical properties. The soil profile opened was 150+cm deep. The soil textural class of the surface layer (0-25cm) of the

Citation: Giday O, Gibrekidan H, Berhe T. Soil fertility characterization in vertisols of southern Tigray, Ethiopia. *Adv Plants Agric Res.* 2015;2(1):7–13. DOI: 10.15406/apar.2015.02.00034

profile and the mean composite surface (0-15cm) soil samples of both sites were clay loam while it was clay for the underlying subsurface layers of the profile. The bulk and particle density values of the layers in the profile varied consistently with depth ranging from 1.18 and 2.51gcm $^{-3}$ at the surface layer to 1.32 and 2.85gcm $^{-3}$ at the bottom layer of the profile, respectively.

The pH of the soil profile decreased consistently with increasing soil depth from 6.3 (slightly acidic) at the surface horizon to 8.2 (strongly acidic) at the bottom of the subsoil. The total N and OM contents of the surface layer of the profile and the mean total N content of the composite surface soil samples of both sites were rated as medium while the composite surface soil samples of site A and B had medium and low OM levels, respectively. The available P content of the soil profile at the surface layer (20.5mg P kg^{-1} soil) and the composite surface soil samples of site A (21.14mg P kg^{-1} soil) and site B (14.33mg P kg^{-1} soil) were in the range of the high available P status.

The soil exchange complex of both the profile and composite surface soil samples of both sites were predominantly occupied by divalent basic cations (exchangeable Ca followed by Mg). The CEC values of the plow layer of the soils in the study area as determined in the profile and the composite surface soil samples were rated as very high. The CEC values of the profile increased inconsistently with increasing soil profile depth from 41.42c mol (+) kg^{-1} at the surface horizon to 50.37c mol (+) kg^{-1} at the upper subsurface (25-98cm) depth of the profile which was also rated as very high throughout its depth. Among the exchangeable cations, all except Na were rated as high to very high and all except K increased with depth consistently.

The results of the study revealed that the physical and chemical properties of the soils are highly variable to each other which disagrees the blanket rate of fertilizer recommendation throughout the country. The turning point to solve the problems should be restoring, maintaining and increasing the fertility status of the soils. These phenomena necessitate soil-crop specific fertilizer recommendation. The nutrient supplying powers of the soils and demanding levels of the plants need further correlation and calibration works to come out with site-soil-crop specific fertilizer recommendation. Therefore, the existing soil fertility problems should be addressed sooner by introducing/developing resistant crop varieties, applying organic and inorganic fertilizers, and other soil fertility management options.

Acknowledgements

None.

Conflict of interest

The author declares no conflict of interest.

References

1. Mureithi JG, Mwaura PM, Nekesa CO. Introduction of legume cover crops to smallholder farms in Gatanga, Central Kenya. In: *Proceedings of the Second Scientific Conference of the Soil Management and Legume Research Network Projects*; 2000. p. 98–102.
2. Desta Beyene. The response of pulse crops to nitrogen and phosphorus fertilizers. *Paper Presented at the Workshop on Review of Soil Science Research in Ethiopia*. Addis Ababa, Ethiopia; 1986. p. 11–14.
3. Mesfin Abebe. *Nature and management of Ethiopian soils*. Alemaya, Ethiopia: Alemaya University of agriculture; 1998. 272 p.
4. Probert ME, Fergus IF, McGarry D, et al. *The properties and management of Vertisols*. UK: CAB International Wallingford; 1987.
5. Eylachew Zewudie. Study on the physical, chemical and mineralogical characteristics of some Vertisols of Ethiopia. In: Wondimagegn Chekol, et al. editors. Proceedings of the 5th Conference of the Ethiopian Society of Soil Science, Addis Ababa, Ethiopia; 2000.
6. Mamo T, Haque I, Kamara CS. Phosphorus status of Ethiopian Vertisols: Management of Vertisols in Sub–Saharan Africa. In: *Proceeding of the conference held at International Livestock Centre for Africa (ILCA);* 1988. p. 232–252.
7. Woldeab A, Mamo T, Bekele M, et al. Soil fertility management studies on wheat in Ethiopia. In: *Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa*. Addis Ababa, Ethiopia: CIMMYT; 1991.
8. Ofla District office of agriculture and rural development; 2011.
9. Bouyoucos GJ. Hydrometer method improvement for making particle size analysis of soils. *Agronomy Journal*. 1962;54:464–465.
10. Baruah TC, Barthakur HP. *A Textbook of Soils Analysis*. New Delhi, India: Vikas Publishing House Private Limited; 1997. 256 p.
11. Carter M. Soil Sampling and methods of analysis. *Canadian Soil Science Society*. Boca Raton, Florid: Lewis Publishers; 1993. 823 p.
12. Walkley A, Black CA. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science*. 1934;37(1):29–38.
13. Jackson ML. Soil chemical analysis. Englewood cliffs, N.J. 582p. Jaiswal, P.C., 2003. *Soil, Plant and Water Analysis*. Kalyani, New Delhi, India: Prentice–Hall Inc; 1958. 441 P.
14. Olsen SR, Cole CV, Watanabe FS, et al. *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. Washington, USA: USDA Circular; 1954;939:1–19.
15. Rowell D. *Soil science: Method and applications*. UK: Addison Wesley Longman Limited; 1994. 350 p.
16. Hesse P. *A Text Book of Soil Chemical Analysis*. Great Britain: John Murry Limited, London; 1972.
17. Young A. *Tropical soils and soil survey*. London, UK: Cambridge University Press; 1976. 468 p.
18. Bohn HL, McNeal BL, O Connor GA. *Soil Chemistry*. 3rd ed. New York, USA: John Willey and Sons; 2001.
19. Brady NC, Weil RR. *The Nature and Properties of Soil*. 13th ed. Asia: Pearson Education; 2002.
20. Esayas A. Some physico–chemical characteristics of the Raya Valley soils, Ethiopia. *EthiopianJournal of Natural Resources*. 2001;3(2):179–195.
21. Tadese T. *Soil, plant, water, fertilizer, animal manure and compost analysis*. Working Document No. 13. Addis Ababa, Ethiopia: International Livestock Research Center for Africa; 1991.
22. Tekalign M, Haque I. Phosphorus status of some Ethiopian soils, II. Forms and distribution of inorganic phosphates and their relation to available phosphorus. *Tropical Agriculture*. 1991;68(1):2–8.
23. Zewdie E. physical, chemical and mineralogical characteristics of major soils occurring in Chercher highlands, Eastern Ethiopia. *Ethiopian Journal of Natural Resources*. 1999;1(2):173–185.

Citation: Giday O, Gibrekidan H, Berhe T. Soil fertility characterization in vertisols of southern Tigray, Ethiopia. *Adv Plants Agric Res.* 2015;2(1):7–13. DOI: 10.15406/apar.2015.02.00034

24. Debele B. *The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia*. Addis Ababa, Ethiopia: Land Use Planning and Regulatory Department, Ministry of Agriculture; 1990.

25. Mamo T, Haque I, Aduayi EA. Soil, plant, water, fertilizer, animal manure and compost analysis manual. *Plant science division working document 13*. Addis Ababa, Ethiopia: ILCA; 1991.

26. Finck A, Vendateswarlu J. Chemical properties and fertility management of Vertisols. In: *Vertisols and rice soils of the tropics*. Symposium Papers 2. Transaction of the 12th International Congress of Soil Science, New Delhi, India; 1982;3:61–69.

27. Mamo T, Haque I, Kamara CS. Phosphorus status of Ethiopian Vertisols: Management of Vertisols in Sub–Saharan Africa. In: *Proceeding of the conference held at International Livestock Centre for Africa (ILCA)*. 1987. p. 232–252.

28. Seyoum M. *Uptake responce of rice (Oryza sativa) to Nitrogen and Phosphors fertilization under lowland conition of Fogera plain, Northern Ethiopia*. An Msc. Thesis, Alemaya University; 2000. p. 1–68.

29. Assen M, Le Roux PAL, Barker CH, et al. Soils of Jelo micro–catchment in the Chercher highlands of eastern Ethiopia: I. Morphological and physicochemical properties. *Ethiopian Journal of Natural Resource*s. 2005;7(1):55–81.

30. Gebreselassie Y. Selected chemical and physical characteristics of soils of Adet Resaerch Centre and its testing sites in north–western Ethiopia. *Ethiopian Journal of Natura Resources*. 2002;4(2):199–215.

31. Negassa W, Gebrekidan H. Forms of phosphorus and status of available micronutrients under different land–use systems of Alfisols in Bako area of Ethiopia. *Ethiopian Journal of Natural Resources*. 2003;5(1):17–37.

32. Food and Agriculture Organization (FAO). *Plant nutrition for food Security: A guide for integrated nutrient management*. FAO Fertilizer and plant nutrition Bulletin 16, Rome, Italy; 2006.

33. Landon JR. *Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics*. Essex, New York: Longman Scientific and Technical; 1991. 474 p.

34. Kebede M. *Physico–chemical properties and classification of soils along the toposequence at Woreta Agricultural Technical Vocational Education and Training College research farm, Ethiopia*. MSc Thesis, Alemaya University, Ethiopia; 2006. 65 p.

35. Hazelton P, Murphy B. *Interpreting soil test results: What do all the numbers mean*? 2nd ed. Sydney: CSIRO Publishing; 2007. 152 p.

Citation: Giday O, Gibrekidan H, Berhe T. Soil fertility characterization in vertisols of southern Tigray, Ethiopia. *Adv Plants Agric Res.* 2015;2(1):7–13. DOI: 10.15406/apar.2015.02.00034