Full Length Research Paper

Soil Classification for Sustainable Water Management in Tikurwuha Watershed, Blue Nile Basin, Ethiopia

Gizachew Ayalew

Debre Tabor University, Faculty of Agriculture and Environmental Sciences, P. O. Box 272, Debre Tabor, Ethiopia. E-mail: gizachewayalew75@yahoo.com

Abstract

This study was conducted during the 2016/17 in Tikurwuha watershed, Blue Nile, Ethiopia to classify soils using FAO/WRB criteria for sustainable water management. Four soil profiles of Awuzet (AP) at eucalyptus plantation, cultivated and grazing lands were described *In-situ* using FAO/WRB guideline. Soil samples were collected from pedogenic horizons and they were analyzed for soil color, texture, bulk density (BD), pH and organic carbon (OC). FAO/WRB soil classification legend was used to classify the soils. Surface soil color was 7.5YR4/2 (yellowish red) for AP0-1 and AP0-2 and 7.5YR5/1 for AP0-3. All profiles, except AP0-3 were clay in texture. Highest OC (4.19%) was registered at the subsurface of AP0-3. Bulk densities of AP0-1, AP0-2 and AP0-3 ranged from 0.98 to 1.37, 0.98 to 1.53 and 98 to 1.23 g cm^{-3}, respectively. All soil profiles were characterized by their acidic nature. Generally AP0-1, AP0-2 and AP0-3 were identified as Luvisols, Vertisols and Cambisols at intensively cultivated land, grazing land and plantation, respectively. This soil classification map, therefor, can facilitate soil and water conservation planning and, thus, it can point to sustainable utilization of water management in the region and other parts of the country with similar agro-ecology.

Keywords: Ethiopia, soil erosion, Tikurwuha; water

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1. Introduction

Agriculture is the mainstay of the Ethiopia's economy where its production is highly dependent on natural resources (Akililu and Graaff, 2007). However, the country remained unable to feed its people. Soil and water resources significantly affected agricultural productivity. On the other hand, water and soil quality degradation which were caused by a number of socioeconomic factors such as deforestation, over cultivation, overpopulation, overgrazing and other inappropriate farming practices reduced productive capacity of the soil (Kumar *et al*., 2014).

Detailed soil data are required to conduct soil evaluation to provide fertility guidance and to advise land users on how to wisely use the land resources mainly water and soil. In other words, if soil data are not used for the purpuses, they could bring soil and soil-related environmental problems, compaction, flooding and poor crop yields (Chintala *et al*., 2014; Prasad, 2014).

Improved understanding of the genesis of soils and their relationships leads to improvements in their use and management. However, the existing soil map of Ethiopia is less usefull in supporting soil water conservation and management interventions. Therefore, to use and manage water, understanding the properties, characteristics and classification of the soils are more required for Tikurwuha watershed, Farta district of Amhara Regional State of Ethiopia. Hence, a number of studies are required to understand the soil genesis and classification and to provide enough data for water related studies at the watershade level (Mesfin, 1998). Therefore, the main objective of this research was to study the morphological and physicochemical characteristics and to classify the soils for sustainable water management in Tikurwuha watershed, Blue Nile Basin, Ethiopia.

2. Materials and Methods

2.1 Description of the Watershed in the Study Area

Tikurwuha watershed is found in Amhara region, south Gonder zone, Farta *woreda*, about 24 km far from Deberetabor town (Figure 1). The total area of the watershed is about 483 ha. The geographical location of the watershed varies from 38º0502500–38º0604500 E to 11º4802200–11º4902600 N.

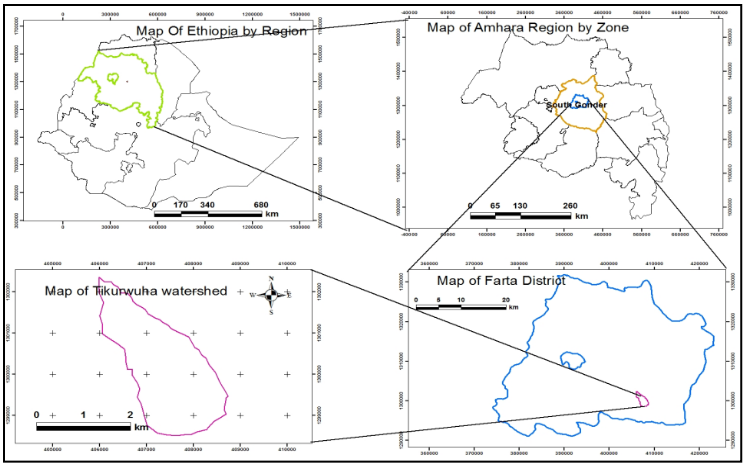

Figure 1. Map of the study area

Most part of the Tikurwuha watershed is being cultivated for crop production (Table 1). The watershed has *wet dega* agroecology with rainfall of greater than1400 mm, altitude 2570-3100 masl. The annual temperature is about 7-25^{0}$_{C.}$

Table 1. Land use /cover of Tikurwuha Watershed

Land Use/Cover	Area (ha)	Percent (%)
Settlement	11.73	2.4
Cultivated land	406.69	84.2
Grazing land	39.92	8.26
Forest land	15.66	3.24
Others	8.98	1.9
Total Area	482.98	100

2.2 Methods

i) Soil Profile Description

Tikurwuha watershed was stratified into eucalyptus plantation, cultivated and grazing lands. Based on soil color and texture, major soil types and their boundaries within each land use/cover types were identified and delineated in the field. Soil profiles were opened and *In-Situ*, described for soil morphological and physicochemical characterizations in each land use/cover type on the bases of FAO/WRB (1998) guideline. A total of 20 soil samples was collected and sent to Amhara Regional state soil laboratory for analyses.

ii) Soil Analysis

Soil bulk density was determined by the method described in Black (1965) where first undisturbed soil samples taken from a core sample of known volume (height 5 cm and diameter 7.2 cm) weighed at field moisture condition. The soil samples were then oven dried at $105^{o}{}_{C}$ for 72 hours until constant weight was obtained and the oven dried samples were weighed again. Bulk density was then computed by dividing the weight of oven dried soil samples to the volume of the sampler. Soil texture was determined by the hydrometer method described in Bouyoucos (1962). Hydrogen peroxide was used to destroy organic matter and sodium hexa-metaphosphate as a dispersing agent. Then, hydrometer readings after 40 seconds and 2 hours were used to determine the silt plus clay, and clay particles in suspension, respectively, whereas the percent of silt were calculated from the difference. Finally, soil textural classes were determined following the textural triangle of the USDA system as described in Rowell (1997). Soil pH was measured potentiometrically using a digital pH meter in the supernatant suspension of 1:2.5 (soil: water ratio) (Chintala *et al*., 2012). The organic carbon (OC) content was analyzed following the wet digestion method described in Walkley and Black (1934).

3. Results and Discussion

3.1 Morphological and Physicochemical Characteristics of AP01

The profile was dug at a longitude of 40º6386E, latitude of 13º1587 N and altitudes of 2881 masl, characterized by intensive cultivation. As shown in Table 1 and 2, the soils were deep, well drained, reddish brown, diffused horizon boundaries and angular blocky structure. They were clayey soils with high aggregate stability, rich in iron and have water dispersible clay. They were found on flat slope and thick soil depth (110 cm) (FAO/WRB, 2006) and are supported by Gizachew *et al*. (2014).

Table 1. Laboratory analysis result for AP02

Depth (cm)	**Horizon**	**Texture**				**BD gcm^{-3}**	**pH /H2O**	**OC %**
		Sand%	**Silt %**	**Clay %**	**Class**			
0-20	AP	13.64	40	46.36	SC	0.98	5.1	1.75
20-40	AB	13.64	38	48.36	C	1.27	5.43	1.48
40-80	B1	31.64	28	40.36	CL	1.28	5.28	1.13
80-110	B2	29.64	28	42.36	CL	1.37	5.53	1.23

Table 2. Morphological description of profile AP01

Horizon	Depth cm	Description
AP	0-20	7.5YR4/2(dry) & 7.5YR4/1 (moist); none crusting, slightly hard, granular blocky structure; no mottle; common roots.
AB	20-40	7.5YR2/1(dry) & 7.5YR2/1 (moist); slightly hard, moderate angular blocky structure; mottle; coarse moderate roots.
BA	40-80	7.5YR2/2 (dry) and 7.5YR2/2 (moist); slightly hard, weak granular blocky structure; sticky.
B2	80-110	Very sticky, fine roots.

3.2 Morphological and Physicochemical Characteristics of AP02

Awuzet soil profile two (AP02) is located in grazing land at a longitude of 40º65', latitude of 13º01' and altitudes of 2925 masl. It is characterized by its middle slope, no microtopography and weak evidence of stratification indicated by soil color and texture change (Table 3). The consistence is loosely attached. It has also very deep (>125 cm). The chemical composition of AP02 is presented in Table 4. Its main use is for livestock grazing and in small classes for rain-fed agriculture purposes. The angular blocky structure with shiny Ped faces in the profile could reflect the existence of relative accumulation of clay and biological pedoturbation (FAO/WRB, 1998) and is supported by Gizachew *et al*. (2014).

Table 3. Morphological characteristics of AP02

Horizon	Depth (cm)	Description
Ah	0-25	7.5YR4/2 (dry) & 7.5YR4/3 (moist); hard, weak blocky structure; hard, none coarse fragment; no mottle.
BA	25-40	10YR3/1 (dry) & 10YR3/2 (moist); sticky, few mottle & roots.
Bt1	40-60	7.5YR2.5/2 (dry) & 7.5YR2.5/3 (moist); very sticky granular blocky structure; coarse moderate roots.
Bt2	60-125	Sticky, fine, very fine roots.

Table 4. Laboratory analysis result for AP02

Depth (cm)	Horizon	Texture				BD Gcm^{-3}	pH /H2O	OC %
		Sand %	Silt %	Clay %	Class			
0-25	Ah	17.64	32	50.36	C	0.98	5.09	2.03
25-40	BA	21.64	16	62.36	C	1.31	5.39	0.71
40-60	B1	15.64	16	68.36	C	1.35	5.27	0.44
60-125	B2	13.64	14	72.36	C	1.53	5.54	0.29

Singh and Agrawal (2003) reported that structural variability could be due to moisture, soil OM and clay contents. Heavier clay contents recorded in the profile was corresponding to the finding of Getachew and Heluf (2007) in an Ayehu research substation. The migration and accumulation of clay in the subsurface could be contributed by the in-situ synthesis of secondary clays, the weathering of primary minerals, or the residual concentration of clays from the selective dissolution of more soluble minerals (Buole *et al*., 2003).

The irregularity of silt could be due to temporal variation in weathering. The result was in agreement with the finding of Naidu (2002) in Karnataka. Similar results were also reported by Arun *et al*. (2002) in India. The low bulk density value at the surface could reflect the increase in contents of sand. This implies that no excessive compaction and restriction to root development (Werner, 1997). As indicated in Table 5, the irregular pattern of pH values with soil depth might be due to downward movement of bases and clay adsorbed sporadically at different layers. This is supported by Buole *et al*. (2003). The highest organic carbon was recorded at the surface layer which could be attributed to the addition of farmyard manure and plant residues as supported by Getachew and Heluf (2007).

3.3 Morphological and Physicochemical Characteristics of AP03

Awuzet soil profile three (AP03) represents soil characterized by a certain development of structure, or has weak evidence of stratification in the profile indicated by soil color and texture change. It is characterized by slight or moderate weathering of parent material and by the absence of appreciable quantities of accumulated clay, organic matter, having moderately developed Cambic B horizon and a Mollic horizon overlying subsoil (Tables 5 and 6). It is found in association with Leptosols and Regosols covered with natural and plantation forest areas of steep slope, hills, mountain and dissected landscapes (FAO/WRB, 2006) . This is supported by Gizachew *et al*.(2014).

Table 5. Morphological characteristics of AP03

Horizon	Depth(cm)	Description
	0-15	7.5YR5/1(dry) & 7.5YR5/2 (moist); none crusting, slightly hard, weak granular blocky structure; fragment; no mottle.
BA	15-40	10YR2/1(dry) & 10YR2/1 (moist); slightly hard, moderate subangular blocky structure; friable, no mottle.
B	40-60	10YR2/2 (dry) & 10YR2/2 (moist); slightly hard, moderate granular blocky structure; sticky, coarse roots. .
BC	60-120	Sticky, fine, very fine roots.

Table 6. Laboratory analysis result for AP03

Depth (cm)	Horizon	Texture				BD	pH	OC
		Sand %	Silt %	Clay%	Class	gcm^{-3}	/H2O	%
0-15	AH	33.64	38	28.36	CL	1.02	5.56	3.64
15-40	BA	27.64	44	28.36	CL	0.98	4.99	4.19
40-60	B	35.64	32	32.36	CL	1.22	5.25	3.11
60-120	BC	27.64	32	40.36	C	1.23	5.37	1.77

3.3 Soil Classification

Based on morphological, physical and chemical characteristics, the soils of the Tikurewuha watershed are classified into three reference soil groups using based on FAO/WRB (1998) legend classification. The reference soil groups are Luvisols, Vertisols and Cambisols (Figure 2). Based on the field observations and laboratory analysis, Tikurwuha soil profile 1 (AP01) could be categorized as Luvisols. This is because Luvisols have red colored clayey soil texture, more than 30 percent clay and blocky structure. This result was in harmony with the finding of Gete (2000) in Anjeni watershed. As per the soil classification legend, AP02 and AP03 fulfill the criteria for Vertisols and Cambisols, respectively. This finding is supported by Gizachew *et al*. (2014).

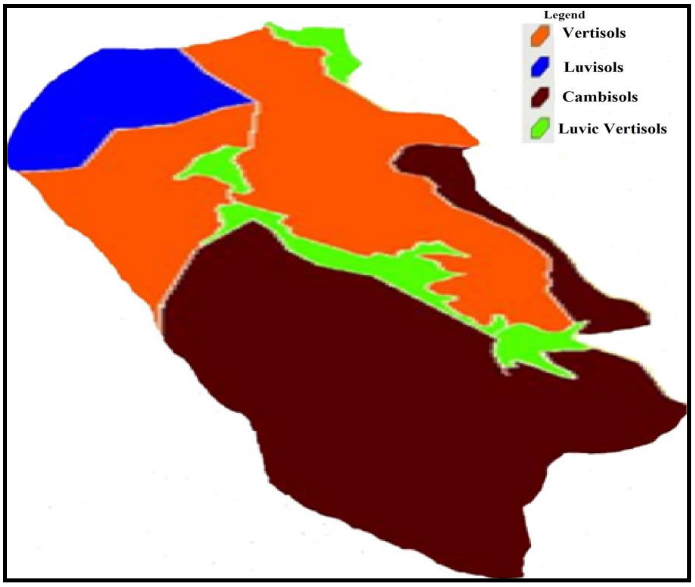

Figure 2. Soil map of Tikurewuha watershed

Conclusions

On the basis of the soil profile descriptions and laboratory analysis, Luvisols, Vertisols, and Cambisols were identified in intensively cultivated lands, grazing lands and eucalyptus plantation of Tikurwuha watershed, respectively. It is also possible to conclude that land use/cover has an effect on soil formation and its characteristics. The classification of soils and its spatial distribution could facilitate sustainable water and soil use and management.The method can also be applied in similar region.

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References

Akililu Amsalu and Graaff De J (2007). Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. Ecological Economics, 61:294-302.

Arun KV, Natarajan S and Sivasamy R (2002). Characterization and classification of soils of lower Palar-Manimuthar watershed of Tamil Nadu. *Agropedolog*y, 12*:* 97-103.

Black CA (1965). Methods of Soil Analysis Part II. Chemical and microbiological characteristics. *Agronomy Monograph No. 9*, American Society of Agronomy, Inc. Madison, Wisconsin, USA, pp.18-25

Bouyoucos GJ (1962). Hydrometer method improved for making particle-size analysis of soils. *Agronomy Journal*, 54:463-465.

Buole SW, Hole FD, McCracken RJ, Southard RJ (2003). Soil Genesis and Classification. 4th ed., Panima Publishing Corporation, New Delhi, Bangalore, 527 PP.

Chintala R, McDonald LM, Bryan WB (2012). Optimization of water potential and nutrient levels for Kentucky bluegrass-white clover mixture of acidic soils. *Biotechnology, Agronomy, Society & Environment:*167-177.

Chintala R, Djira G, Devkota M, Prasad R, Kumar S (2014). *Modeling the effect of temperature and precipitation on crop residue potential for the North Central Region of the United States*. Agricultural Research. http://dx.doi.org/10.1007/s40003-014-0099-5

FAO/WRB (1998).World Reference Base for Soil Resources. *World Soil Resource Report*. FAO, Rome. PP.84-88.

FAO/WRB (2006). Guidelines for soil description, Fourth edition, Rome.

Getachew F, Heluf Gebrekidan (2007). Characterization and fertility status of the soils of Ayehu research substation in Northern highlands of Ethiopia. East African Journal of Sciences, 1(2): 160-169.

Gete Zeleke (2000). Landscape Dynamics and Soil Erosion Process Modeling in the Northwestern Ethiopia Highland. African Studies Series A16, Bern, Switzerland, pp.196

Gizachew Ayalew, Yihenew Getachew, Eyasu Elias, Chiristy VB (2015). Soil Classification in Yigossa Watershed, Lake Tana Basin, Highlands of Northwestern Ethiopia, Journal of Agricultural Science, 7(1): 113p.

Kumar S, Nakajima T, Mbonimpa EG, Gautam S, Somireddy UR, Kadono A, Fausey N (2014). Long-term tillage and drainage influences on soil organic carbon dynamics, aggregate stability, and carbon yield. *Soil Science & Plant Nutrition*, 60 (1): 108-118.

Mesfin Abebe (1998). Nature and management of Ethiopian soils. Alemaya University of Agriculture. Alemaya, Ethiopia. 272p.

Naidu LGK (2002). Characterization of sugarcane soils of Karanataka. *Agropedology,* 12: 157-163.

Rowell DL (1997). Soil Science: Methods and Applications. Longman Singapore Publishers Ltd., Singapore. 350p.

Singh IS, Agrawal HP (2003). Characteristics and classification of some rice growing soils of Chandauli district of Uttar Pradesh. *Agropedology,* 13:11-16.

Walkley and Black CA (1934). An examination of different methods for determining soil organic matter and the proposed modifications by the chromic acid titration method. *Soil Science*, 37: 29-38.

Werner MR (1997). Soil quality characteristics during conversion to organic orchard management. *Applied Soil Ecology,* 5:151-167.