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Full Length Research Paper

The soils of the Delbo Wegene watershed in the Wolaita Zone in Southern Ethiopia are being studied in order to plan proper land management

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The soils of the Delbo Wegene watershed of Southern Ethiopia were characterized along toposequence for the development of land management plan for sustainable soil management practices. Four pedons along toposequence were studied. Delbo Wegene watershed is located between 06°52' 45.9'' and 06°53'34.8'' N latitude and between 37°48' 10.5'' and 37°48'42.4''E longitude, with altitude ranging from 2100 to 2300 m.a.s.l. The soils were generally dark reddish brown to very dark brown and very deep (> 150 cm). The overall friable consistency, low bulk density (1.0 to 1.26 gm/cm^3), sub angular to angular blocky structure, high total porosity (53 to 61%) indicated that the soils have good physical condition for plant growth. The soils were slightly (pH: 5.8) to moderately acidic (pH: 6.4). Organic carbon content, available micronutrients and cation exchangeable capacity of the soils decrease with soil depth. However, exchangeable cations increase with increasing soils depth. Available phosphorus content of the soils ranged from very low to high. However, available Cu content of the soils were marginal to deficient. The upper and middle pedons with argilic subsurface horizons were classified as Typic Paleustults (Soil Survey Staff, 1999). These soils correlate with Cutanic Luvisols (WRB, 2006). The lower and toe slope pedons with mollic epepedon and cambic subsurface horizon were classified as Typic Haplustepts. These soils correlate with Haplic Cambisols (WRB, 2006). The result indicated that the distribution and properties of the soils vary along the toposequence in the watershed.

Key words: Soil characteristics, soil classification, Delbo-Wegene watershed.

INTRODUCTION

Successful agriculture to meet the increasing demands of food, fiber and fuel from the decreasing per capita land, requires the sustainable use of soil because soil is an important non-renewable land resource determining the agricultural potential of a given area. The study and understanding of soil properties and their distribution over an area has proved useful for the development of soil management plan for efficient utilization of limited land resources. Moreover, it is very important for agro-technology transfer (Buol et al., 2003).

Ethiopia has diverse soil resources largely because of diverse topography, climatic conditions and geology (Abayneh, 2001). The soil resource of the whole country was studied at a scale of 1:2,000,000 (Wijntje-Bruggeman, 1984). In addition, the soil resource assessment under the River Basins Project alone has covered more than 40% of the country at 1:250,000 scale (Abayneh, 2001). These studies are of small scale and not comprehensive enough to draw development planning at watershed level. Consequently, sustainable soil management practices that are based on the understanding of soil system are not available for most part of the country (Fikre, 2003). Hence, there is a need to commence detail soil characterization works.

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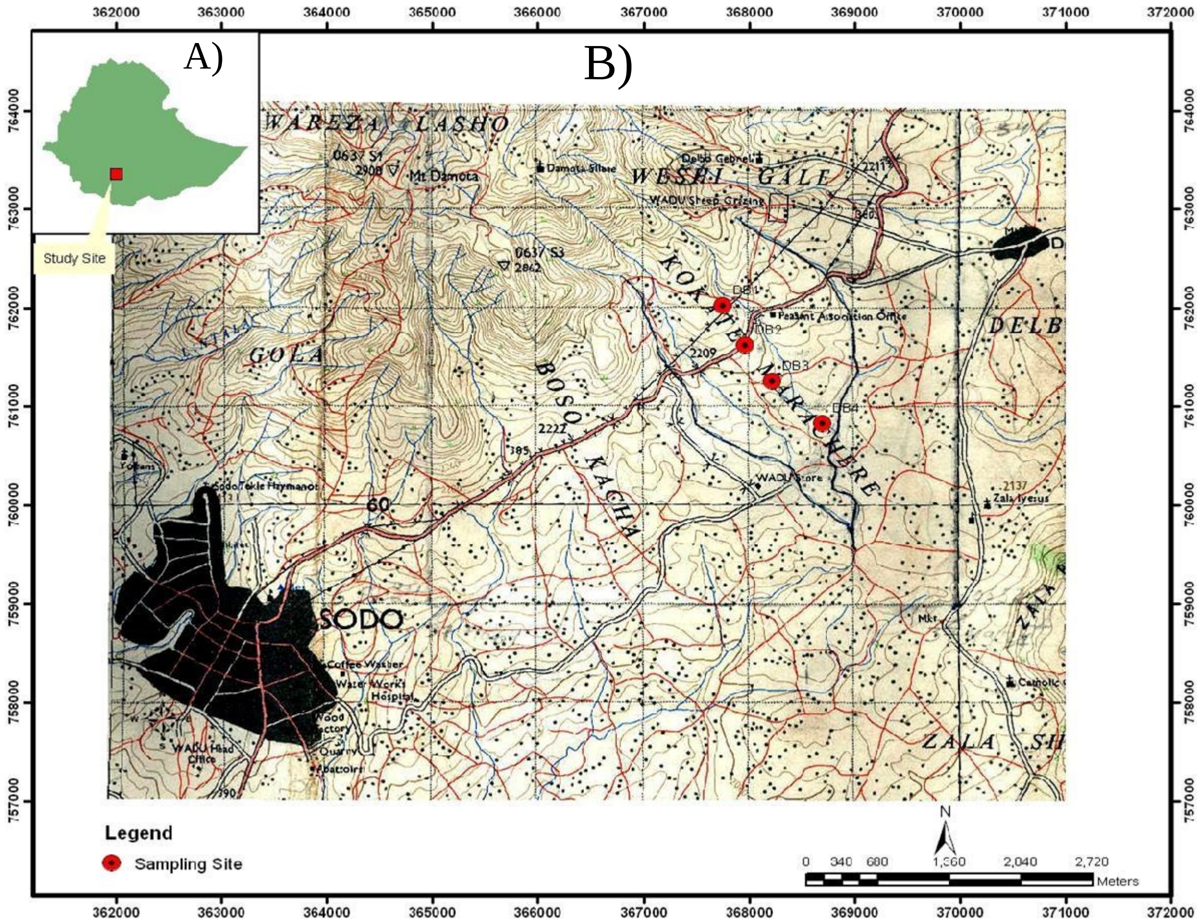

Figure 1. Map of Ethiopia (A) showing location of the study area (Delbo Wegene Watershed) and (B) topographic map of the study area showing locations of sampling sites.

The dominant soils of the Wolayita area are reported to be Nitosols (FAO/UNESCO, 1974), which are sesquioxidic and moderately to strongly acidic (Mesfin, 1998). Abayneh et al. (2006a) also indicated the existence of Rhodic Nitisols (WRB, 1998) around Wolaita area. Fikre (2003) also confirmed the occurrence of Alfisols around the same area. In addition, according to Mulgeta (2006) Ultisols, Inceptisols and Entisols are present around Wolaita area on diverse topography.

An increase in agricultural production, particularly rain fed cropping, is a function of soil, climate and agro-technology. The proper understanding of the nature and properties of the soils of the country and their management according to their potentials and constraints is imperative for maximization of crop production to the potential limits (Abayneh and Brehanu, 2006). However, the morphological, physical and chemical characteristics of soils of Delbo Wegene watershed area in relation to nutrient retention and management alternatives not well documented. Therefore, the purpose of this study was to characterize and classify soils of Delbo Wegene watershed, on the topo-sequence to generate baseline information, which will be important for formulating the management alternatives for different soil types identified. The specific objectives of the study were to: (1)

Determine the morphological, physical and chemical characteristics and (2) Classify the soils according to Soil Taxonomy and World Reference Base Legend.

MATERIALS AND METHODS

Description of the study area

The Delbo Wegene watershed is located in Wolayita Zone of Southern Nations, Nationalities and Peoples Regional State, Ethiopia (Figure 1). It is located at about 8 km East of Sodo town and 368 km South of Addis Ababa. Its geographical extent is between 06°52' 45.9" and 06°53'34.8" N latitude and between 37°48' 10.5"and 37°48' 42.4" E longitude with altitude ranging from 2100 to 2300 m.a.s.l. It has a total area of 922 ha.
The geology of the study area is dominated by ignimbrite

Table 4. Moisture content and available water capacity of soils of Delbo Wegene watershed.

Horizon(cm)	Moisture Content		Available water	TP	Macropore	AWC(mm/m)
	33 kPa	1500 kPa				
	Wt%		Vol%			
			Upper slope			
0- 34	35.58	24.61	10.97	61	25	104.31
34-73	29.73	21.64	8.88	59	26	
73-99	30.82	20.59	11.97	53	17	
99- 136	30.72	20.28	12.53	54	17	
			Middle slope			
0- 18	32.39	18.12	16.48	53	16	111.34
18-45	30.78	20.84	11.44	56	21	
45-62	30.08	22.77	9.06	53	15	
62-93	32.69	25.27	9.31	54	12	
			Lower slope			
0- 22	25.74	17.41	9.50	57	27	
22-50	26.90	18.61	9.53	56	25	118.03
50- 106	29.18	17.34	14.60	54	18	
			Toe slope			
0- 22	24.50	17.42	8.07	56	28	130.64
22- 66	27.73	16.33	13.17	57	25	
66-98	25.04	11.58	16.16	53	23	

50%, 30 - 40%, 20 to 40% and 10 - 35% at upper, lower, toe and middle slope positions, respectively.

Soils at the upper and middle slope positions have discernable increase in clay content with soil depth compared to those found at lower and toe slopes, which have slight clay increase. Although the abundance varies, clay cutans were observed in all pedons. According to Buol et al*.* (2003), the presence of clay cutans or clay skins and textural differentiation in the profile are indicators of clay migration. The accumulation of clay in the subsurface horizon could have been contributed by the *in situ* synthesis of secondary clays, the weathering of primary minerals in the B horizon, or the residual concentration of clays from the selective dissolution of more soluble minerals of coarser grain sized in the B horizon (Buol et al., 2003).

The bulk density of the soils was in the range of 1.00 in the A horizon of the upper pedon to 1.26 gm cm^{-3} in the Bt2 horizon of the middle pedon (Table 3). Higher OM content in the A horizon makes soils loose, porous and well aggregated, thereby reducing bulk density (Hilel, 1980).In all pedons, the lowest bulk densities were found at the surface horizons, which have higher OM content.

The correlation analysis have confirmed that bulk density is negatively correlated with OC (r = -0.61) and TN (r = -0.64) and positively correlated with clay content (r = 0.73).

Bulk densities values of the soils increased with soil depth from A to B horizons. However, the bulk density values of the surface horizons were less than the critical values (1.4 g/cm^3) for agricultural use (Hillel, 1980). This implies that no excessive compaction and no restriction to root development (Werner, 1997).

Total porosity (TP) of the soils ranged from 53 to 61 (V%) (Table 3) and macro pores (pores at field capacity) between 12 and 28 (V%). According to Brady and Weil (2002), ideal total pore space values, which are acceptable for crop production, are around 50%. Hence, the soils have an acceptable range of total porosity values for crop production.

Gravimetric water content of the soils at field capacity (33 kPa) ranged from 24.50 - 35.58% while the amount at permanent wilting point (1500 kPa) was between 11.58 - 25.27% (Table 4). The volumetric plant available water content (AWC) of the soils varied from 8.07 - 16.48 % on horizon basis. According to Beernaert (1990), available

Table 7. Organic carbon, total nitrogen and available phosphorus content of the soils at Delbo Wegene watershed

Horizons	Depth(cm)	OC	TN %	C/N	Av.P. (mg/kg)
Upper slope					
A	0-34	2.40	0.25	10	3.36
B	34-73	1.67	0.18	9	3.28
Bt1	73-99	1.31	0.18	7	3.11
Bt2	99-136	1.47	0.15	10	2.98
Bt3	136-163	0.79	0.09	8	2.55
BC1	163-188	1.05	0.15	7	2.54
BC2	188-205	0.47	0.08	8	1.98
Middle Slope					
A	0- 18	2.38	0.23	10	4.24
A2	18-45	2.06	0.25	8	3.14
Bt1	45-62	1.99	0.16	12	2.78
Bt2	62- 93	0.51	0.06	9	2.64
Bt3	93-127	0.49	0.07	7	2.25
BC1	127-154	0.39	0.05	8	9.36
BC2	154-200	0.21	0.03	7	7.00
Lower slope					
Ap	0- 22	1.99	0.17	12	13.76
A	22-50	1.95	0.15	13	4.68
Bt	50-106	1.12	0.09	13	4.04
C	106- 180	0.75	0.07	11	6.84
Toe slope					
Ap	0- 22	1.46	0.12	12	5.00
A	22-66	1.56	0.18	9	4.76
AB	66-98	1.33	0.11	12	4.48
Bt	98- 127	0.79	0.06	13	4.26
BC	127- 180	0.77	0.08	10	4.12

around Bako area, Ethiopia.

The exchangeable Na content of the soils is low and the exchangeable sodium percentage (ESP) of the soils was also less than 2%. This indicates that there is no sodicity problem in these soils. According to Brady and Weil (2002), ESP of 15% is considered as critical for most crops.

According to Sims (2000), the range of critical values for optimum crop production for K, Ca and Mg are from 0.28 - 0.51, 1.25 - 2.5, and 0.25 - 0.5 cmol (+)/kg soil, respectively. Accordingly, the exchangeable K, Ca and Mg content of the soils are above the critical values. However, this does not prove a balanced proportion of the exchangeable bases. Potassium uptake would be reduced as Ca and Mg are increased; conversely uptake of these two cations would be reduced as the available supply of K is increased (Havlin et al., 1999).

In addition, the ratio of exchangeable Ca/Mg should not exceed 10/1 to 15/1 to prevent Mg deficiency and also the recommended K/Mg are < 5/1 for field crops, 3/1 for vegetables and sugar beets and 2/1 for fruit and greenhouse crops (Havlin et al., 1999). The Ca/Mg ratio of the studied soils was in the range of 2 - 9 indicating that the response of crops to Mg is not likely. The K/Mg ratio of the studied soils varied from 0.2 to 1.2 and hence it is within the acceptable range for crop production.

The base saturation percentage of the soils is less than 50 in all surface and some parts of the subsurface horizons of the upper and middle pedons. The lower and toe slope pedons, however, have a base saturation percentage greater than 50 in all surface and some parts of the subsurface horizons. The organic carbon (OC) content of the soils generally decreased with soil depth in all pedons (Table 7). The OC content ranged from 0.21 in

Table 8. Available micronutrients content of soils at Delbo Wegene watershed.

Horizons	Depth (cm)	Fe	Cu	Zn	Mn
		Mg/kg soil			
		Upper slope			
A	0-34	50.73	1.03	14.01	113.39
B	34-73	22.95	0.73	12.43	46.70
Bt1	73-99	21.85	0.66	11.66	44.42
Bt2	99-136	20.45	0.75	13.18	38.24
Bt3	136-163	20.01	0.70	7.79	28.42
BC1	163-188	17.56	0.73	11.90	25.59
BC2	188-205	15.40	0.46	3.37	63.10
		Middle slope			
A	0- 18	49.41	0.51	15.74	77.48
A2	18-45	49.35	0.48	14.90	44.95
Bt1	45-62	39.18	0.35	14.70	15.14
Bt2	62- 93	2.00	0.18	1.19	6.53
Bt3	93-127	2.29	0.13	0.42	5.26
BC1	127-154	2.13	0.09	0.09	14.04
BC2	154-200	2.97	0.07	0.22	17.12
		Lower slope			
Ap	0- 22	20.61	0.26	15.29	35.02
A	22-50	57.20	0.37	14.52	13.88
Bt	50-106	49.30	0.29	10.54	12.65
C	106- 180	13.13	0.15	4.09	11.13
		Toe slope			
Ap	0- 22	32.49	0.48	13.77	41.34
A	22-66	47.50	0.51	13.53	33.31
AB	66-102	47.72	0.51	12.01	29.04
Bt	102- 127	15.07	0.40	4.47	19.43
BC	127- 180+	13.02	0.31	1.67	21.32

Table 9. DTPA-extractable Fe, Zn, Cu, and Mn for deficient, marginal and sufficient soils.

Category	Fe	Zn	Mn	Cu
		Mg/kg soil		
Low(deficient)	0-2.5	0-0.5	< 1.0	0-0.4
Marginal	2.6 - 4.5	0.6 - 1.0	-	0.4 - 0.6
High(sufficient)	> 4.5	> 1.0	> 1.0	> 0.6

Source: Havlin et al. (1999).

base saturation less than 50% between the mollic epepedon and a depth of 180 cm were classified as Inceptisols. Although the soil moisture and temperature regimes of the pedons were not measured, using the mean annual and monthly temperature and moisture distributions of the region as recommended by Van Wambeke (1992), the study area was characterized by isotermic temperature and ustic moisture regimes,

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