Agropedology 2003, 13 (2), 1-9

Influence of land management on morphological, physical and chemical properties of some soils of Bako, Western Ethiopia

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Abstract : The influence of different land management systems of research farm, farmer's field and virgin land on morphological, physical and some chemical properties of soils of Bako were studied. The pedons of the research farm and virgin land were classified as Hapludalfs and that of the farmer's field as Dystrudepts at great group level. The surface horizon were somewhat darker and had low total porosity than the sub-surface horizons. The Ap horizon of Dystrudepts had 64 per cent clay whereas it was 30 per cent in pedon of research farm and 26 per cent in virgin soil. Water retentions at field capacity and permanent wilting point increased with depth in cultivated soil but it was not so in virgin land. Available water holding capacity was higher in P2 than P1 and P3 (except Bt3 horizon) The soils were acidic and pH ranged from 5.2 to 6.8 in different horizons. The surface horizons had higher organic carbon being 5.9 per cent in virgin land but it's values decreased with depth in all the pedons. Total N also followed a similar trend. The cation exchange capacity ranged from 11.0 (A horizon of Alisol) to 36.0 cmol (p+) kg^{-1} (Ap horizon of Nitisol). Base saturation was more than 34 per cent in different horizons.

Additional Key words: *Farmer's field, land use, research farm, virgin land, soil properties*

Introduction

The livelihood of human beings in countries with subsistence farming and centuries old farming practices depend on soil quality. The success of soil management to maintain soil quality depends on understanding the responses of soils to land uses and management practices over time. The changes induced due to the changes in land management often modify soil properties and in turn agricultural productivity. Research results indicate that land management influences physical, chemical and biological properties of soils (Martel and Mackenzie 1980; Saini and Grant 1980; Kang 1993).

Periodic assessment of important soil properties and their responses to changes in land management is necessary in order to improve and maintain the fertility and productivity of soils. In Ethiopia, soil degradation in considerable tracts of land is taking place due to improper land use, irrigation practices and intensive mechanized farming (Wakene and Heluf 2003). However, information available on this aspect to give recommendation for optimal and sustainable utilization of the country's land resource and that of Bako area in particular is scanty. Therefore, the present study is aimed to investigate the influence of land management on the morphological, physical and selected chemical parameters of some soils in Bako, Western Ethiopia.

Materials and methods

Study Area

The study area falls at and around the Bako Agricultural Research Centre (BARC) located in the East Wollega Zone of the Oromia National State of Western Ethiopia, about 260 km west of Addis Ababa. Bako lies between 09^0 06' N latitude and 37^0 09' E longitude at an altitude of 1650 m above msl. The climate of the area is a typical sub-humid with mean annual rainfall of 1244 mm (uni-modal type). The rainy season starts in April and continues upto October with maximum rainfall in the months of June to August. The minimum, maximum and average air temperatures at the Centre are 14.1, 27.9 and 20.6 ^{0}C, respectively. Tertiary and quaternary rhyolite and basalt are the major rock types occurring in topographic positions from gently undulating to dissected hills (Anonymous 1996). The soils are locally known as Biye Dima meaning red soil.

Site selection and soil sampling

Three representative pedons were selected from three different land management systems during the summer of 2000 (Table 1). The Pedon 1 is under intensive cultivation with tractor since 1964 and the field receives 75:33 kg ha^{-1} of N:P fertilizers annually for maize and sorghum production. The Pedon 2 is cultivated for grain crops continuously for about forty years following the traditional farming practices. The use of NP fertilizers on this field was started only in 1993. The Pedon 3 is a virgin land.

The soils currently under different land management systems are presumed to have similar morphological, physical and chemical properties prior to the present land uses. The morphological description and horizon designation of the pedons were made following the procedures outlined in Soil Survey Manual (Soil Survey Staff 1993) and classified as per Soil Taxonomy (Soil Survey Staff 1999) and the FAO/UNESCO Soil Grouping System (FAO 1990).

Laboratory analysis

Bulk density was determined in un-

Table 1. Site characteristics

Site	Location	Altitude (m) above msl	Physiography	Slope (%)	Parent material	Drainage class	Moisture condition	Water table (m)	Erosion	Land use / crop
P1: Research farm	175 m from BRC Weather Station	1645	Summit, convex slope	5% to W	Basalt	Well drained	Moist throughout	> 2.0	Slight (sheet)	Experimental plots
P2: Farmer's field	300 m on 5^0 from main road to BRC	1755	Middle, convex slope	7% to N	Basalt	Well drained	Moist throughout	1.4	Slight to moderate	Maize
P3: Virgin land	100 m on 90^0 from main road to BRC	1665	Middle, convex slope	5% to SE	Basalt	Well drained	Moist throughout	> 1.7	Slight (sheet)	Virgin (open shrub)

Abbreviations: BRC - Bako Research Centre; W – West; N - North; SE - Southeast

Table 2. Morphological properties of soils

Depth (cm)	Horizon	Boundary	Colour		Textural class	Structure	Consistency		
			Dry	Moist			Dry	Moist	Wet
Pedon 1 : Research farm: Hapludalf (Alisol)									
0-16	Ap	as	5YR 3/3	5YR 3/2	scl	c2sbk	h	fr	sp
16-40	Bt1	gs	5YR 4/6	2.5YR 3/6	sc	m2sbk	h	fr	sp
40-125	Bt2	cw	2.5YR 4/6	2.5YR 3/4	c	m1abk	h	fr	sp
125-200^{+}	C	cs	-	-	scl	-	-	-	-
Pedon 2 : Farmer's field: Dystrudept (Cambisol)									
0-20	Ap	as	5YR 3/3	7.5YR 3/2	c	c3sbk	h	fr	sp
20-90	Bw1	gs	5YR 4/6	7.5YR 3/4	cl	c2sbk	h	fr	sp
90-140	2Bw1	gs	2.5YR 4/6	2.5YR 3/4	c	c2abk	h	fr	sp
140-160^{+}	2Bw2	gs	5YR 4/6	2.5YR 3/6	c	m1sbk	h	fr	ssp
Pedon 3 : Virgin land: Hapludalf (Nitisol)									
0-13	A	gs	5YR 3/2	10YR 2/2	l	m2gr	sh	vfr	ssp
13-30	Bt1	gs	5YR 3/3	7.5YR 3/4	c	m2sbk	h	fr	sp
30-50	Bt2	gs	2.5YR 3/6	2.5YR 2.5/4	c	c2sbk	h	fr	sp
50-140	Bt3	cs	2.5YR 4/6	2.5YR 3/6	c	c1sbk	h	fr	ssp
140-165^{+}	C	-	-	-	c		-	-	-

disturbed soil clods collected in cylinders (core samplers) of 56 mm length and 42 mm diameter from each horizon except for the C-horizons. Particle density was determined by the pycnometer method (Blake 1965). Particle-size distribution was determined by hydrometer method as described by Day (1965). The soil-water potential was measured at 33 kpa and 1500 kpa with pressure plate apparatus and available water holding capacity was calculated as difference between water potentials at 33 kpa and 1500 kpa (Klute 1965). Soil moisture content at sampling was determined gravimetrically. Total porosity was estimated from the values of bulk density *(Db)* and particle density *(Dp)* as:

$$\text{Total porosity (\%)} = \left(1 - \frac{Db}{Dp}\right) \times 100$$

Soil pH (1:2.5) ,organic carbon, total nitrogen, and CEC (Ammonium acetate) were determined by standard procedures (Jackson 1958 ; Black 1965).

Results and discussion

The site characteristics and morphological properties of the pedons are presented in Table 1 and Table 2, respectively. The morphological features indicate that the pedons of the research farm (Pedon 1) and the virgin (uncultivated) land exhibit argillic (Bt) horizons whereas the pedon of the farmer's field indicate significant change in colour, texture and structure.

The structure of all pedons varies from sub-angular to angular blocky with depth, except surface horizon of Pedon 3, which is granular. The boundary of the surface horizons in Pedon 1 and 2 is abrupt and smooth due to ploughing whereas the boundary of pedon 3 is gradual and smooth due to the absence of anthropogenic activities.

Data (Table 3) indicate that in pedons 1 and 3 the clay content increases with depth qualifying for an argillic horizon and base saturation is > 35% throughout. Thus, the soils qualify for Alfisols order and Hapludalfs great group as per Soil Taxonomy (Soil Survey Staff 1999). The soils of the farmer's field are, however, classified as Dystrudepts. Based on the salient features associated with the respective pedons, the soils of pedons 1, 2 and 3 qualify for Alisol, Cambisol and Nitisol Soil Groups, respectively as per the FAO/ UNESCO Soil Grouping System (FAO 1990).

The bulk density of Pedon 1 is higher than the others (Table 3), may be due to compaction by heavy farm machinery and low organic matter content. This is in agreement with the findings of Girma (1998). The bulk density of the soils in the farmer's field and the virgin land increased with depth whereas that of the research farm decreased with depth. The lowest particle density (2.26 Mg m^{-3}) observed in the surface and subsurface horizon of the virgin land might be attributed to the relatively higher organic carbon content in this soil than in the soils of other land management systems.

The lowest total porosity (36.20%) was observed in the soils of research farm

Table 3. Physical properties of soils

Depth (cm)	Horizon	Sand	Silt	Clay	Dp	Db	Total porosity (%)	θ (%, w/w)	Water content (mm m^{-1})		
		(%)			Mgm^{-3}				33 kpa	1500 kpa	AWHC
Pedon 1 : Research farm: Hapludalf (Alisol)											
0-16	Ap	60	10	30	2.46	1.57	36.2	19.3	275.2	173.8	101.4
16-40	Bt1	44	6	50	2.46	1.40	43.1	22.0	317.6	226.3	91.3
40-125	Bt2	34	10	56	2.50	1.41	43.6	23.3	355.7	243.7	112.0
125-200	C	42	26	32	2.59	-	-	-	-	-	-
Pedon 2 : Farmer's field: Dystrudept (Cambisol)											
0-20	Ap	16	20	64	2.45	1.06	56.7	45.0	411.9	275.8	136.1
20-90	Bw1	28	34	38	2.38	1.11	53.4	41.0	465.5	334.5	131.0
90-140	2Bw1	22	18	60	2.51	1.31	47.8	36.7	525.9	384.9	141.0
140-160	2Bw2	24	18	58	2.52	1.35	-	-	-	-	-
Pedon 3 : Virgin land: Hapludalf (Nitisol)											
0-13	A	44	30	26	2.26	1.16	49.8	39.2	403.9	303.3	100.6
13-30	Bt1	42	18	40	2.32	1.25	48.8	30.0	347.7	266.6	81.1
30-50	Bt2	34	22	44	2.37	1.28	48.6	31.0	396.4	285.4	110.0
50-140	Bt3	34	20	46	2.31	1.28	49.2	33.0	449.0	247.4	201.6
140-165	C	38	14	48	2.41	-	-	-	-	-	-

Abbreviations : Dp - Particle density; Db - Bulk density; θ - Soil water content (w/w); FC - Field capacity; PWP - Permanent wilting point; AWHC - Available water holding capacity.

Table 4. Some chemical properties of the soils

Depth (cm)	Horizon	pH (H_2O)	Organic carbon (%)	Total N (%)	C:N ratio	CEC ($cmol_c$ kg^{-1})	Base saturation %
		Pedon 1 : Research farm: Hapludalf (Alisol)					
0-16	Ap	5.2	1.24	0.08	15.5	11.0	35
16-40	Bt1	5.2	0.72	0.05	14.4	12.8	34
40-125	Bt2	5.3	0.61	0.06	10.2	12.0	47
125-200+	C	5.5	0.38	0.04	9.5	11.6	49
		Pedon 2 : Farmer's field: Dystrudept (Cambisol)					
0-20	Ap	6.0	3.39	0.23	14.7	31.2	57
20-90	Bw1	5.7	0.79	0.08	9.9	18.0	40
90-140	2Bw1	5.7	0.51	0.06	8.5	22.6	43
140-160+	2Bw2	5.9	0.44	0.05	8.8	18.8	58
		Pedon 3 : Virgin land: Hapludalf (Nitisol)					
0-13	A	6.3	5.90	0.33	17.9	36.0	62
13-30	Bt1	6.0	2.16	0.14	15.4	26.8	55
30-50	Bt2	6.0	1.24	0.09	13.8	21.2	67
50-140	Bt3	6.8	0.87	0.08	10.9	14.2	53
140-165	C	5.6	0.55	0.06	9.2	16.4	47

and the highest (56.73%) in the soil of farmer's field. Total porosity decreased with depth in the farmer's field whereas it increased with depth in the research farm. The soil water content was highest (45.0%) in the surface soil of the farmer's field and lowest (19.3%) in the surface layer of the research farm. The water retention in soils at field capacity and permanent wilting point are higher in the virgin land and farmer's field. The soil having higher amounts of clay and organic matter retained more moisture even at permanent wilting point.

The lowest soil pH value (Table 4) was recorded in the surface soil of the research farm probably due to continuous removal of basic cations by high yielding crop varieties, use of acidifying inorganic NP fertilizers and intensive cultivation. Kang (1993) and Bouman *et al.* (1995) also reported decrease in pH due to intensive cultivation and use of inorganic fertilizers. The pH (6.3) was relatively higher in the A horizon of the virgin land. The soil of the research farm (P1) had relatively low organic carbon in comparison to farmer's field (P2) and the virgin land (P3). The distribution of the total soil N followed the similar trend of distribution as that of organic carbon. The highest C: N ratio was recorded in the surface horizons irrespective of cultivations. The CEC of the soils varied markedly both among and within pedons (Table 4) and it decreased with depth. The low CEC and organic carbon contents in the research farm are due to intensive cultivation.

Conclusion

It is concluded that the different land use/cultivation and associated management practices have significant influence on bulk density, organic carbon content, soil reaction more particularly in surface horizons of soil. The changes due to mechanical ploughing alone are not pronounced because actual intensive farming and mechanized cultivation in the research farm has started only a few decades back. Nevertheless, most of soil properties of the farmer's field which was continuously cultivated with traditional tillage equipment were generally closer to that of the virgin land than to the research farm. This indicates that subsistence farmers have conservation based soil management that sustained the soil productivity for centuries. However, in addition to soil analysis, plant analysis in field experiments conducted over large area may provide better clue for soil management for sustainable productivity of soils in this region.

Acknowledgement

The authors acknowledge the Agricultural Research and Training Project of the Ethiopian Agricultural Research Organization for funding and the Alemaya University for facilities for this study.

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Received : September, 2003; Accepted November, 2003