ORIGINAL ARTICLE

Pedological Characterization, Fertility Status and Classification of Some Typical Soils of Bako Tibe and Toke Kutaye Districts of Western Showa, Ethiopia

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ABSTRACT

Purposive maize farm field selection was carried out in two districts of western Showa, Ethiopia. Four representative farm fields were selected based on landforms and other physiographic attributes in humid highland and sub humid mid altitude maize growing areas of Toke Kutaye and Bako Tibe districts. Four soil profiles were opened and characterized. Pedons are formed under udic and perudic moisture and iso-thermic temperature regimes for both districts. The soils were very deep, well-drained reddish brown to dark reddish brown loamy sand to sandy clay loams, with thick reddish brown loamy sand top and sub soil for Bako Tibe and Toke Kutaye. Three pedons had clayey top and sub soils. The pH of surface soil ranged from 3.26 -5.52 which was very strongly acidic to strongly acidic. The soil organic carbon contents of the surface four pedons ranged from 2.07 to 2.69 % which were in medium to high but very low to high for the subsurface horizons. Both the highland pedons have 20.06 to 54.17 cmol kg^{-1}soil CEC that was in medium to very high, while 10.82 to 23.52 cmol kg^{-1}soil CEC for two mid altitudes, which was low to medium. The total nitrogen concentration is 0.19 to 0.23 % for top soil, which was low to medium range, and 0.03 to 0.07 % for sub surface horizon, which was in very low range. According to USDA Soil Taxonomy, the four pedons were classified as Typic Hapludalfs (Nitisols according to WRB). The four pedons were different in physicochemical properties, indicating the need to characterize soils to give site-specific fertilizer recommendations for maize production.

Keywords: fertility, pedons, physicochemical properties

INTRODUCTION

Soil degradation and low rate of mineral fertilizers applications is a serious threat to food security in sub-Saharan Africa (Henao and Baanante, 1999). For instance, the major driving force of land degradations are nutrient depletion, complete removal of crop residues, crop production with low levels of nutrient inputs and lack of adequate soil conservation practices in Ethiopia (Bojo and Cassels, 1995); longer cultivation (Wu *et al*., 2003). As a result, decline in soil fertility has a marked impact on plant growth and yield, grain quality, production costs and the increased risk of soil erosion. Conventional agriculture has certain limitations in terms of maintaining long-term soil fertility (Charpentier *et al*., 1999). A continental soil nutrient balance study in 38 sub-Saharan African countries for 35 crops reported negative soil nutrient balances for all three macro-nutrients (N, P, K) with mean annual losses of 22 kg N, 2.5 kg P and 15 kg K ha^{-1} (Stoorvogel and Smaling, 1990). The highest rate of nutrient depletion was observed in Ethiopia with aggregated national scale nutrient balances estimated to be -41 kg N, -6 kg P and -26 kg K ha^{-1} (Stoorvogel and Smaling, 1990).

Inappropriate soil management practices such as low external inputs and internal nutrient cycles, and severe soil erosion contribute for soil and land degradation in Ethiopia. As a result, negative major plant nutrients balances are common problems in many parts of Ethiopia (Elias *et al*., 1998). Different soil types exhibits varying characteristics due to differences in micro-morphological, morphological, physical, chemical and mineralogical properties (Ukut et al., 2014**)**.) Variations in soil forming factors and processes operating on different parent materials, under different climatic, topographic, and biological conditions over varying periods would cause this variations (Soil survey Staff, 1993). Fagbami (1990) reported the diversity of soil type is a major reason behind allocation of land to wrong uses. Overall, human population pressure, climate change and lack of land capability classification systems are the major causes of soil fertility depletion in Ethiopia regardless of variations among agroecosystems.

Hence, to maintain agricultural land at optimum level of fertility and productivity, great attention has been given to assess the physical and bio-chemical properties of the soil resources under different famers maize fields. Soil characterization and classification could provide information for the understanding of the micro-morphological, physical, chemical, mineralogical and microbiological properties of the soil (Ogunkunle, 1986). Eswaram (2005) reported soil characterization is a major building block for understanding the soil, classifying it and getting the best understanding of the environment. Monitoring of nutrient status for assessing the degree of nutrient mining in an agro-ecosystem is very crucial. The change in soil nutrient stocks over time has to be measured in order to quantify the extent of nutrient mining and maintaining the cropping system for sustainable crop production. Soil properties that change with duration and intensity of weathering provide vital clue toward the pedogenesis of the studied soil (Bera et al., 2015). According to Giessen *et al*. (2009) characterization and/or evaluation of soil properties is a master key for describing and understanding the status and qualities of the major nutrients in soils. Assessing soil physicochemical properties is used to understand the potential status of nutrients in soils under different land uses (Wondowosen and Sheleme, 2011). Soil characterization provides the information for our understanding of the physical, chemical, mineralogical and microbiological properties of the soils we depend on to grow crops, sustain forests and grasslands as well as support homes and society structures (Ogunkunle, 2005). Eswaram (2005) soil characterization data helps to aid in the correct classification of the soil and enable others place the soils in their taxonomies or classification systems and to serve as a basis for more detailed evaluation of the soil as well as gather preliminary information on nutrient, physical or other limitations needed to produce a capability class for crop production. This knowledge can ascertains whether the specified land use types are useful for a given production system and used to meet plants requirement for rapid growth and better crop production (Shishir and Sah, 2003). A detailed study of the soil characteristics and classification will provide baseline information on the physical, chemical and mineralogical properties of the soil for crop production, land use planning and management. Owing to the fact that Bako Tibe and Toke Kutaye districts is an intensively maize producing districts and not much study has been done on the soils of the area. Some typical soils of Bako Tibe and Toke Kutaye district based on site identification, description and characterization have reported in terms of their morphological characteristics, physico-chemical properties and their classification according to the United States Department of Agriculture (USDA) Soil Taxonomy (SSS, 2006) and the FAO-World Reference Base [IUSS Working Group WRB. 2014). In addition, the finding reports on the soil fertility trends of the districts

Therefore, it also serves the users in land use planning and sustainable agricultural production in the area. Therefore, the objective was to characterize and classify the soils Bako Tibe and Toke Kutaye districts of western Showa, Ethiopia and to recommend management practices required for sustainable crop production.

MATERIALS AND METHODS

Description of the study area

The study was conducted in 2013 cropping seasons in Bako Tibe and Toke Kutaye Districts of west Showa zone of Oromia Regional National State, Ethiopia (Fig 1). The study areas are located at Jato Driki and Shakka in Bako Tibe with a pedon designated as GTP-S01 and TUP-S02 and at Babichi and Koleba in Toke Kutaye with pedons named as SBP-S03 and GKP-S04. The relevant site characteristics of the study areas are indicated in Table 1. The altitudes of the sites are 1727 and 1778 m.a.s.l. for Jato Driki and Shakka in Bako Tibe; and 2322 and 2262 m.a.s.l., respectively for Koleba and Babichi and in Toke Kutaye. The soils are formed on flat plains with gradients ranging between 2.5 to 3; and 2 to 2.5 %. The Surface characteristics are indicated moderate rill, inter-rill and sheet erosion without depositions for the four sites. Bako Tibe and Toke Kutaye soil profile had well drained and slow run-off.

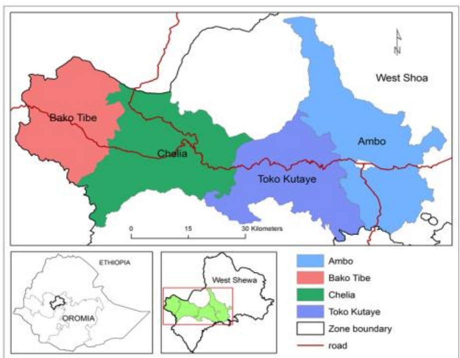

Figure1: Study district in West Shewa Zone of Oromia, Ethiopia

The nearby weather data for both districts are presented in Figure 2-4. The long term data from weather station of Bako Agricultural research center and National Meteorological Service Agency are indicated the areas receive mean annual rainfall of 1265 and 1293 mm (MBARC, 2014 and NMSA, 2014b) for Bako Tibe and 1045 mm for Toke Kutaye (NMSA, 2014a) with unimodal distribution. Bako Tibe have warm humid climate with mean minimum, mean maximum and average air temperatures of 14, 28.5 and 21.2 °C. While Toke Kutaye has a cool humid climate with the mean minimum, mean maximum and average air temperatures of 8.9, 27.4 and 18.1°C, respectively.

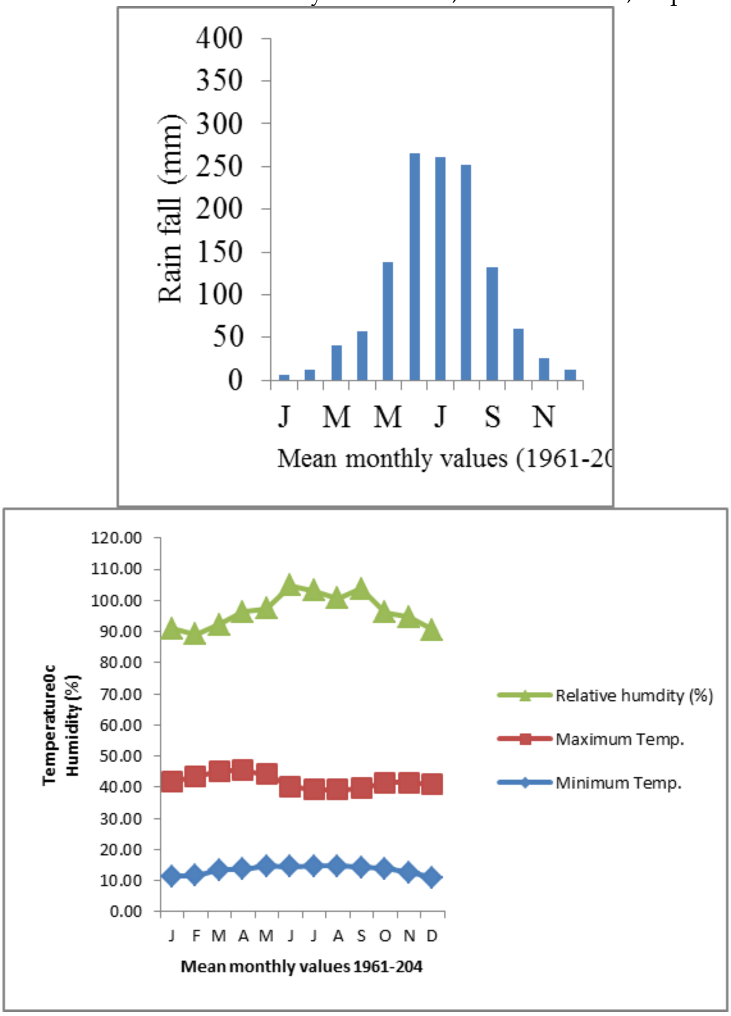

Figure 2. Mean monthly rainfall and temperature data for (GTP-S01) from 1961-2014

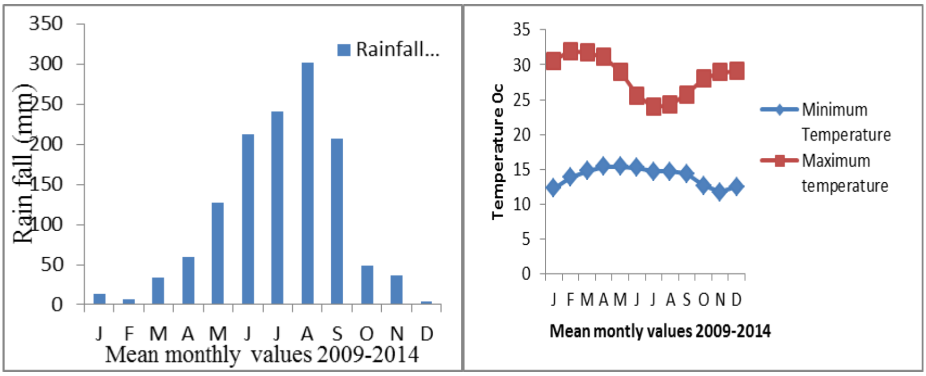

Figure 3. Mean monthly rainfall and temperature data for (TUP-S02) from 2009-2014

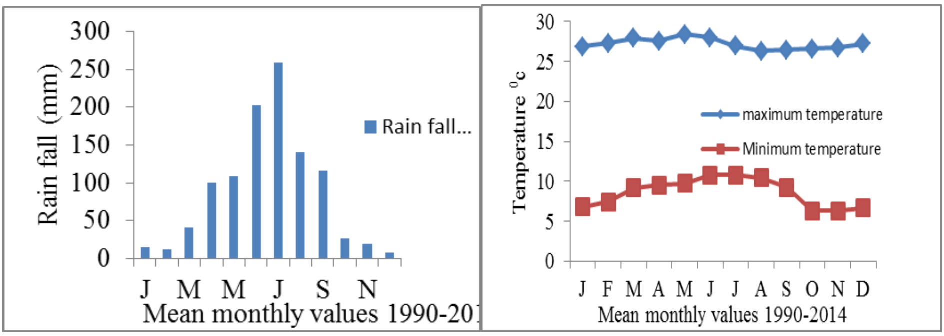

Figure 4. Mean monthly rainfall and temperature data for (SBP-S03 and GKP-S04) from 1990-2014

Soil sampling and profile opening

The representative sites for soil profile description and sampling were selected randomly around maize growing areas in mid altitude and highland areas using Ethiopian traditional system based on altitude and mean daily temperature (Dereje 2011; Gemechu, 1977; and Hurni, 1995). Data on landform, soil morphological characteristics, elevation, slope gradient, vegetation and land use or crops were collected from four observation sites that were selected to represent some major landforms and soils of the selected farm maize. Four soil profiles, two from each district, were identified and dug to represent the major soil types. The opened soil profiles had 250 cm width, 150 cm length and 200 cm depth in the east to west direction using GPS compass. The soil profiles were studied, described and sampled according to FAO Guidelines for Soil Profile Description (FAO, 2006). The soil profiles were geo-referenced using Global Positioning System (GPS).The profile layer of the soil was differentiated and measured. The soil samples were collected from bottom up according to profile horizons. The soil samples collected from each horizon were air dried and passed through 2 mm sieve for determination of most soil physical and chemical properties. Finally, the collected soil samples were processed following standard procedures and used for physical and chemical analysis.

Soil physical analysis

Soil color (dry and moist) was determined using the Munsell color chart (Munsell Color Company, 2009).

Undisturbed soil sample was taken by core sampler, which has 66 and 42 mm diameter and height, respectively and dried at 105°C for 24 h for the determination of bulk density, which was estimated by dividing the oven dried soil sample taken with core sampler to the volume of core sampler. The hydrometer method was used to determine the particle size distribution following Day (1965) procedure.

Soil chemical Analysis

Soil pH was measured potentiometrically using digital pH meter in the supernatant suspension of 1:2.5H_2O, 0.01M $CaCl_2$, and 0.1M KCl. Cation exchange capacity of the soil (CEC) and exchangeable bases were determined by saturating soil with neutral 1M NH_4OAc (ammonium acetate) and the adsorbed $NH4^+$ were displaced by using 1M KCl and then determined by Kjeldahl distillation method for estimation of CEC of the soil (Chapman, 1965). The exchangeable bases (Ca^{2+}, Mg^{2+}, Na^+ and K^+) were determined by atomic absorption spectrophotometer (Anderson and Ingram, 1996). Percent base saturation was estimated from the sum of exchangeable bases as a percent of the CEC of the soil.

Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrated with sodium hydroxide as described by Mclean (1965). Total nitrogen was determined following Kjeldahl procedure as described by Jackson (1958). Total phosphorous was determined following Bray-II procedure as described by Bray and Kurtz (1945). Soil Organic matter was determined following wet digestion methods as described by Walkley and Black (1934).

Classification of soil

The filed and soil pysico-chemical laboratory analysis data were used for pedological characterization. The diagnostic surface and sub-surface horizon were done using the soils guideline of USDA Soil Taxonomy (SSS, 2006). The soils are classified to the family level of the USDA Soil Taxonomy (SSS, 2006) and FAO World Reference Base (IUSS Working Group WRB, 2007 and 2014).

Statistical analysis

Pearson's simple correlation coefficient was executed using Statistical Analysis software 9.0 (SAS, 2008) to establish the relationship between different parameters of soil properties.

RESULTS AND DISCUSSION

Soil Morphological Characteristics

The data for selected morphological properties are indicated in Table 2. The soil depths of the profiles varied from 160 cm deep and 200 cm very deep. There was slight variation between the two mid altitude pedons in soil horizon while the pedons on the highland were similar. The diagnostic epipedons of the four pedon is mollic and premature structure. The sub surface horizons (Bt) was Agric and well developed in all the different maize farm fields under udic and isothermic for mid altitude and perudic and Isothermic for highland soil moisture and temperature.

The colour of surface soil was very dark red (2.5YR3/2) and dark red brown ((2.5YR2.5/4) when moist soil condition for the four maize field soil pedon (Table .2). In dry condition the surface soil colour ranged from red (2.5YR2.5/6) to dark red brown (2.5YR2.5/4) for mid altitude; and red (2.5YR4/6) to dark red brown (2.5YR2.5/4) for highland areas of maize fields.

The top surface horizons (plough layer) had slight colour variation among maize farm fields (Table 2). The surfaces of soil horizon have the same hue (2.5YR) with varying chroma ranging from (2.5/4 to 3/6) when moist. Most colours of the subsurface soil horizon were dark reddish brown having similar hue (2.5 YR) and with varying chroma and value of ranging from (2.5/4 to 5/8). Similarly, Wakene (2001) were found colours of most of the subsurface soil horizons were dark reddish brown having the same hue (2.5YR) with slight variation in value and chroma (3/4 to 3/6) for both moist and dry soils. He stated low organic carbon content that is supposed to be responsible to the darkness of surface horizons of the weathered Alfisol that has been due to intensive cultivation for the last three decades. The subsurface horizon have dominant colour of red in dry soil condition, which may be indicating the presence of iron. Similarly, Murphy (1959) and Wakene (2001) reported that redness is due to the presence of iron oxide in the subsurface horizons.

Table 1. Site characteristics of the pedons

Pedon	Location	AEZ	Altitude	Land form	Slope %	Land use / Vegetation	SMR	STR
GTP-S01	N 9^{0}01'20 E 37^{0}13'29	Sub humid mid altitude	1730	flat	2.5	Agriculture (Maize, tef, Sorghum, hot Pepper, sweet potato haricot bean, soybean, mango, sugarcane and banana) Dominant vegetation includes (Cordia tree, Acacia spp, *Eucalyptus spp,* Croton, Ficus tree)	Udic	Isothermic
TUP-S02	N 8^{0}59'31'' E 37^{0}21'53''		1778	flat	3		Udic	Isothermic
SBP-S03	N 8^{0}71'21 E 37^{0}42'	Humid highland	2322	flat	2	Agriculture (Tef, wheat, barley, maize, faba bean, field pea and Niger seed) Dominant vegetation includes (Acaia spp, *Eucalyptus spp and* Croton tree)	Perudic	Isothermic
GKP-S04	N 8^{0}9'8 E 37^{0}72'		2262	flat	2.5		Perudic	Isothermic

AEZ=Agroecological zone, SMR= soil moisture regime, STR= soil temperature regime

The structure of the soil was from weak to strong sub angular blocky for the four maize farmers field (Table 2). Similar result was reported by (Wakene, 2001). Soil consistency was similar among the different maize farmers field of different soil surface horizons. It was sticky and plastic, and friable consistency for all horizons of maize fields. Soil consistency is an inherent soil characteristic and are reflection of the particle size composition of the soil, high organic matter content changed stickiness and plasticity of surface soil layer on the virgin land.

Soil physical properties

Soil texture

The textural classes of the soils for four-farm maize fields are clay are indicated in (Tables 2, 3, 4, 5 and 6). All the four maize farm soils were clay in texture throughout soil horizon indicting soils of different farm fields have medium CEC, and have good moisture holding capacity. Tolessa (2006) and Wakene (2001) found similar result. Odeh *et al*. (2003) reported soil texture to be the most important attribute affecting physical and chemical processes in a soil. The silt to clay ratio (0.26 to 0.49) in the maize farm fields which was low.

Table 2. Morphological characteristics of pedons in different maize fields of mid altitude and highland areas of western Showa, Ethiopia

Pedon	Horizon	Depth (cm)	Texture	Soil color		Structure	Consistence
				Moist	Dry		
GTP-S01	Ap	0-29	C	db (2.5YR3/2)	r(2.5YR2.5/6)	SCSB	Hd,fr,SP
	Ab	29-78.5	C	drb(2.5YR 3/4)	rb(2.5YR4/4)	MCSB	Hd,fr,SP
	B+1	78.5 – 119	C	r(2.5YR4/8)	r(2.5YR4/8)	MCAB	Hd,fr,SP
	B+2	119 -1 63	C	rb(2.5YR4/4)	r(2.5YR4/6)	WCSB	Hd,fr,SSP
	BC	163-200	C	dr(2.5YR3/6)	drb(2.5 YR3/4)	------	------
TUP-S02	A	0-20	C	dr(2.5YR3/6)	drb(2.5YR2.5/4)	SCSB	Hd,fr,SP
	B+1	20-54	C	rb(2.5YR 4/4)	r(2.5YR4/6)	MCSB	Hd,fr,SP
	B+2	54 – 89	C	drb(2.5YR3/4)	r(2.5YR5/6)	MCAB	Hd,fr,SP
	B+3	89 -1 29	C	rb(2.5YR4/4)	r(2.5YR4/6)	WCSB	Hd,fr,SSP
	BC	129-200	C	r(2.5YR4/6)	r(2.5 YR4/8)	------	------
SBP-S03	A	0-26	C	db(2.5YR3/2)	r(2.5YR4/6)	SCSB	Hd,fr,SP
	Ab	26-48	C	drb(2.5YR 2.5/4)	drb(2.5YR3/4)	MFSB	Hd,fr,SP
	B+1	48 – 94	C	db(2.5YR3/2)	r(2.5YR4/8)	MCAB	Hd,fr,SP
	B+2	94 -1 42	C	drb(2.5YR2.5/4)	r(2.5YR4/6)	WMSB	Hd,fr,SSP
	BC	142-200	C	drb(2.5YR3/4)	drb(2.5 YR3/4)	------	------
GKP-S04	A	0-20	C	drb(2.5YR2.5/4)	drb(2.5YR2.5/4)	SCSB	Hd,fr,SP
	Ab	20-63	C	drb(2.5YR 3/4)	dr(2.5YR3/6)	WFSB	Hd,fr,SP
	Bt1	63 – 102	C	yr(5YR 5/8)	yr(5YR4/6)	MCAB	Hd,fr,SP
	Bt2	102 -1 29	C	rb(5YR4/4)	rb(5YR5/4)	WMSB	Hd,fr,SSd
	BC	129-1 60	SCL	yr(5YR5/6)	rg(5 YR5/2)	------	------

C= clayey, SCL= snad clay loam, WFSB = weak fine sub angular blocky, SCSB = strong coarse sub angular blocky, MCAB = moderate coarse angular blocky, WMSB = weak medium sub angular blocky, Fr =friable, Hd = hard, SP = sticky and plastic, Shd = slightly hard, SSP = slightly sticky and plastic, MMC = moderate medium crumb.

A similar result was reported by Achalu *et al*. (2012) stating that higher clay fraction and lower silt to clay ratio recorded in the cultivated land attributed to the impacts of farming practices. The amount of soil texture distributions were varied among farms. Similarly Achalu *et al*. (2012) found soil physical properties changes with the change in land use systems and its management practices.

Tillage operations enhance oxidation of organic matter and aggravate soil structural deterioration (Wakene, 2001). The tillage practices could facilitate clay particles translocation within the different soil horizon.

Bulk density and moisture holding capacity

The bulk densities of the surface soils of the four maize farm fields were ranged from 1.29 to 1.49 mg/m^3 (Table 3-6). The bulk densities of sub surface soils ranged from 1.30 to 1.55 mg/m^3 (Tables 5-8). The higher soil bulk densities in the sub surface soil horizon than soil surface horizon can be attributed to the higher soil organic matter content in the latter (Gregorich *et al.*, 1994; Wakene, 2001; Achalu *et al.*, 2012). Soils having low and high bulk density respectively exhibit favorable and poor soil physical conditions, respectively (Hajabbasi *et al.*, 1997; Patil and Jagdish, 2004).

The moisture holding capacity of the surface soil of four-farm maize fields ranged from 17.96 to 29.36 % w/w (Tables 3-6). In sub surface soil horizon, moisture holding capacities were ranged from 10.77 to 33.88 % w/w (Tables 3-6). Soil moisture holding capacity showed much variation among sub surface soil horizon. The soil moisture capacity was decreased with increased soil depth. This can be attributed to the higher soil organic matter content of the surface horizon than the sub surface horizon. Similar result was reported by Achalu *et al* (2012).

Table 3. Important physico-chemical properties of soils at different horizons of GTP-S01 profile at Shaka, Bako Tibe district of western Showa, Ethiopia

Parameters	Depth (cm)				
	0-29	29-78.5	78.5 – 119	119 -1 63	163-200
pH(H_2O)	4.78	5.37	5.79	5.72	5.02
Organic carbon (%)	2.42	0.97	0.74	0.58	0.51
Organic matter (%)	4.17	1.67	1.28	1.00	0.88
CEC (cmol kg^{-1})	23.52	16.76	13.95	12.89	12.95
Total N (%)	0.20	0.08	0.08	0.06	0.06
Total P (mg kg-1)	52.67	7.24	4.94	4.12	28
C: N	12.10	12.13	9.25	9.67	8.50
EC μs/cm	44.5	47.1	53.0	73.6	70.8
Na (cmol kg^{-1})	1.59	0.81	0.97	1.04	0.60
K (cmol kg^{-1})	0.92	0.46	0.53	0.56	0.35
Mg (cmol kg^{-1})	2.83	1.08	1.42	1.42	1.44
Ca (cmol kg^{-1})	6.59	3.40	3.49	2.59	2.49
BS (%)	51	34	46	44	38
Clay (%)	61.25	86.25	88.75	91.25	73.75
Silt (%)	17.50	5.00	5	2.50	3.0
Sand (%)	21.25	8.75	6.25	6.25	23.0
Exc. Al^3 Acidity	0.23	0.14	0.17	0.14	0.21
Exch.Al^{3+}	Trace	Trace	Trace	Trace	Trace
pH (0.1MKCl)	3.45	4.97	4.26	4.20	4.60
pH (0.01$CaCL_2$. $6H_20$)	4.52	5.00	5.56	5.55	4.91
Bulk density(mg/m^3)	1.49	1.42	1.55	1.56	1.69
Moisture holding capacity (%)	17.96	25.27	12.00	11.43	18.29
Total sulfur	130.44	37.54	36.87	32.6	32.14

Opened on maize field of Gutu Tolera

Table 4. Important hysic-chemical properties of soils at different horizons of TUP-S02 profile at Jato Dirki, Bako Tibe district of western Showa, Ethiopia

Parameters	Depth (cm)				
	0-20	20-54	54 – 89	89 -129	129-200
pH(H_2O)	4.56	4.66	5.57	4.69	5.2
Organic carbon (%)	2.69	1.40	1.17	0.97	0.58
Organic matter (%)	4.64	2.41	2.02	1.67	1.00
CEC (cmol kg^{-1})	18.55	16.44	17.00	12.63	10.82
Total N (%)	0.23	0.12	0.09	0.08	0.07
Total P (mg kg-1)	50.2	0.69	0.47	0.39	2.67
C:N	11.70	11.67	13.00	12.13	8.29
EC µs/cm	114.3	76.0	52.6	52.5	46.5
Na (cmol kg^{-1})	1.13	0.48	0.37	0.35	0.32
K (cmol kg^{-1})	0.65	0.30	0.25	0.20	0.17
Mg (cmol kg^{-1})	3.67	1.42	2.25	2..76	2.65
Ca (cmol kg^{-1})	5.12	2.54	2.81	2.65	2.55
BS (%)	57	29	33	25	53
Clay (%)	51.25	73.75	78.75	81.25	78.75
Silt (%)	25	10	7.50	7.50	10
Sand (%)	23.75	16.25	13.75	11.25	11.25
Exc. Al^3 acidity	0.27	0.29	0.31	0.24	0.21
Exch.Al^{3+}	Trace	Trace	Trace	Trace	Trace
pH (0.1MKCl)	3.40	3.44	3.51	3.36	3.56
pH(0.01$CaCL_2$. $6H_20$)	4.46	4.60	4.70	4.66	5.11
Bulk density(mg/m^3)	1.29	1.30	1.43	1.46	1.35
Moisture holding capacity (%)	27.77	15.54	20.62	25.36	14.00
Total sulfur	151	56.31	42.85	42.67	23.13

Opened on maize field of Takele Uluma

Soil chemical properties

Soil pH

The pH (H_2O) of top soil surface horizon ranged from 4.48 to 5.52 for the four pedons (Tables 3, 4, 5 and 6). The soil reaction of surface soils was varied from very strongly acidic to strongly acidic (Jones 2003, and Landon (1991). The result was in agreement with Achalu *et al*. (2012) for western Ethiopia in cultivated fields. The lower value of soil pH under the cultivated land may be due to the depletion of basic cations in crop harvest and due to its highest microbial oxidation that produces organic acids, which provide H ions to the soil solution lowers its soil pH, value (Achalu *et al*., 2012). Frossard et al. *(*2000) reported the acidic nature with low soil pH obtained from all the representative land uses might be attributed to the fact that, soils were derived from weathering of acidic igneous granites and leaching of basic cations such as K, Ca and Mg from the surface soil.

Organic carbon

The organic carbon contents of the surface soil were ranged from 2.07 to 2.69 % found from medium to high range based on (FAO, 1990; and Landon (1991) (Tables 3, 4, 5 and 6). This might be due to cultivation, which increases soil aeration, which enhances decompositions of SOM. Besides SOM produced in soils of cultivated land are removed with harvest causing for its reduction in values of OC content. The result was in agreement with Achalu *et al*. (2012). Similarly, studies conducted by Lal (1996); Mandiringana et al. (2005) and Michel et al. (2010) indicated the lower percentage of soil OC content in cultivated land. The organic carbon concentration was decreased with increasing soil depth starting from surface horizon to subsurface horizon. Similar result was reported by Tolessa (2006) and Wakene (2001). This might be due to surface soil is the most active parts of biologically soil system in soil funa and flora and receiving different organic sources of litter and residues. Therefore, the soil has high moisture holding capacity and poor in aeration. The soils are very deep well drained.

Table5. Important physic-chemical properties of soils at different horizons of SBP-S03 profile at Babichi, Toke Kutaye district of western Showa, Ethiopia

Parameters	Depth (cm)				
	0-26	26-48	48 – 94	94 -142	142-200
pH(H_2O)	4.48	4.72	4.84	5.32	5.32
Organic carbon (%)	2.07	1.44	2.85	0.66	0.39
Organic matter (%)	3.57	2.48	4.91	1.14	0.67
CEC (cmol kg^{-1})	20.06	23.28	23.17	22.32	24.35
Total N (%)	0.19	0.13	0.1	0.08	0.04
Total P (mg kg^{-1})	80.26	11.04	7.52	6.27	25.32
C:N	10.89	11.08	28.50	8.25	9.75
EC µs/cm	54.4	52.6	71.4	52.4	53.4
Na(cmol kg^{-1})	1.75	1.73	2.50	2.75	2.75
K(cmol kg^{-1})	1.01	0.95	1.18	1.78	1.48
Mg (cmol kg^{-1})	1.75	1.25	1.08	1.08	1.07
Ca (cmol kg^{-1})	6.03	3.04	2.15	2.05	2.11
BS (%)	53	30	30	34	30
Clay (%)	56.25	73.75	78.75	81.25	78.75
Silt (%)	27.50	17.50	10	10	5
Sand (%)	16.25	8.75	11.25	8.75	16.25
Exc. Al^3 Acidity	0.41	0.33	0.29	0.22	0.15
Exchangeable Al^{3+}	Trace	Trace	Trace	Trace	Trace
pH (0.1MKCl)	3.26	3.41	3.53	3.77	3.98
pH(0.01$CaCL_2$. $6H_20$)	4.37	4.61	4.68	5.27	5.09
Bulk density(mg/m^3)	1.42	1.52	1.42	1.49	1.46
Moisture holding capacity (%)	29.02	10.77	12.15	13.44	12.44
Total sulfur	123.91	60.99	54.33	43.47	13.21

Opened on maize field of Sisay Belete

Total nitrogen

The total nitrogen concentrations of the surface soil ranged from 0.19 to 0.23 % (Tables 3-6). The total N concentrations found in low to medium range according to FAO (1990) and Landon (1991). This might be due to the crop harvest removal of crop residue and continuous cultivation. Similarly, the lower total N in cultivated land was in agreement with the findings of (Abbasi *et al.*, 2007; Jaiyeoba, 2003; Heluf and Wakene, 2006). The low N fertility could be attributed to the continuous monocropping (Wakene *et al.*, 2004). Total nitrogen concentrations were reduced as the depth increases from surface soil through all sub surface horizon (Tables 3 to 6). The result was in agreement with Tolessa (2006) and Wakene (2001). The total N was in medium range and the soil has a good potential for agricultural crop production.

Table 6. Important hysic-chemical properties of soils at different horizons of GKP-S04 profile at Koleba, Toke Kutaye district of western Showa, Ethiopia

Parameters	Depth (cm)				
	0-20	20-63	63 – 102	102 -1 29	129-1 60
pH(H_2O)	5.52	5.48	5.62	5.69	5.83
Organic carbon (%)	2.49	1.36	0.86	0.70	0.35
Organic matter (%)	4.29	2.34	1.48	1.21	0.60
CEC(cmol kg^{-1})	28.84	29.91	29.18	34.08	54.17
Total N (%)	0.21	0.11	0.08	0.06	0.03
Total P (mg kg^{-1})	30.51	4.20	2.86	2.38	16.22
C:N	11.86	12.36	10.75	11.67	11.67
EC µs/cm	93.0	84.2	69.7	166.7	86.3
Na(cmol kg^{-1})	4.75	4.25	2	1.25	1.5
K(cmol kg^{-1})	1.07	2.07	1.18	0.44	0.59
Mg (cmol kg^{-1})	4.92	2.25	3.67	4.25	4.78
Ca (cmol kg^{-1})	6.83	4.29	5.59	6.17	6.57
BS (%)	61	43	43	36	25
Clay (%)	66.25	76.25	76.25	68.75	33
Silt (%)	17.5	15	5	15	20.75
Sand (%)	16.25	8.75	18.75	16.25	46.25
Ex.Al^3 acidity	0.12	0.17	0.15	0.11	0.30
Exch.Al^{3+}	Trace	Trace	Trace	Trace	Trace
pH (0.1MKCl)	4.10	4.03	4.06	4.08	4.12
pH(0.01$CaCL_2$. $6H_20$)	5.45	5.42	5.43	5.57	5.72
Bulk density (mg/m^3)	1.38	1.45	1.46	1.42	1.30
Moisture holding capacity (%)	29.36	28.48	21.12	22.54	33.86
Total sulfur	136.96	51.6	43.47	27.85	9.91

Opened on maize field of Gutama Kuma

C: N ratio

The C: N ratio of the surface soil ranged from 10.89-12.10:1 (Tables 3-6), found in medium range, which is good quality (Msanya et al., 2000). The C: N ratio of the subsurface soil ranged from 8.29-28.50:1 found in low to very high (Tables 3-6), showing good to poor quality (Msanya et al., 2000; and Landon, 1991). The ratio of total organic carbon and total nitrogen is the traditional guide to the nature of the organic matter present in the soil (Brady and Weil, 2002). The C:N ratio of the surface soil was in narrow range. Similarly Achalu *et al*. (2012) found cultivated land recorded narrow C: N ratio. This might be due to different tillage practices applied during land preparation which enhance decomposition process in the soil system. Aeration during tillage and increased temperature that enhance mineralization rates of OC than organic nitrogen could probably be the causes for the lower level of C: N ratio in cultivated land (Achalu *et al*., 2012). Abbasi *et al*. (2007) found narrow C: N ratio in soil of cultivated land concurs due to higher microbial activity and more CO_2 evolution and its loss to the atmosphere in the top (0-20 cm) soil layer resulted to the narrow C:N ratio. Soil management practices are necessary for improving the narrow range of C: N ratio. Haney et al. (2012) reported introducing management schemes to improve the C:N ratio and increase microbial activity should result in increased soil fertility/soil biology and highly productive and sustainable systems. Therefore, it is important to sustain to restore intensively cultivated lands through best management practices, for instances improving soil properties by managing using crop rotation, composting, returning crop residues to the fields and cultivating no more than necessary and adding organic materials are very crucial.

Table 7. Identification of diagnostic surface and sub-surface epipedons

Profile No	Diagnostic Epipedons	Diagnostic Sub Surface Horizon	D features
GTP-S01	Mollic	Agric	SMR= Udic, STR: isothermic
TUP-S02	Mollic	Agric	SMR= Udic, STR: isothermic
SBP-S03	Mollic	Agric	SMR=perudic, STR=Isothermic
GKP-S04	Mollic	Agric	SMR=perudic, STR=Isothermic

GTP= Gutu Tolera, TUP= Takele Uluma, SBP= Sisay Belete, GKP= Gutama Kuma maize field

Total Phosphorous

The total phosphorous for surface soil ranged from 30.51 to 80.26 mg kg^{-1}which is high relative to the P content of mineral soils (FAO, 1990; and Landon (1991). The sub surface soil horizons had lower amounts total phosphorous as compared to surface horizons of all the pedons. Similar result was reported by Tolessa (2006) and Wakene (2001). The phosphorus was varying among four maize farm fields, which might be due to variations in soil management during cultivation period by farmers. Tekalign and Haque (1987) and Dawit *et al*. (2002) reported that the availability of P in most soils of Ethiopia vary due to fixation, abundant crop harvest and erosion. Similarly, Paulos (1996) found variations in available P contents in soils are related with the intensity of soil disturbance, the degree of P- fixation with Fe and Ca ions.

Table 8. Details of soil classification/nomenclatures

Profile no	Order	Suborder	Great group	Sub group	Family	
GTP-S01	Alfisol	Udalfs	Hapludalfs	Typic Hapludalfs	Clayey Hapludalfs	Typic
TUP-S02	Alfisol	Udalfs	Hapludalfs	Typic Hapludalfs	Clayey Hapludalfs	Typic
SBP-S03	Alfisol	Udalfs	Hapludalfs	Typic Hapludalfs	Clayey Hapludalfs	Typic
GKP-S04	Alfisol	Udalfs	Hapludalfs	Typic Hapludalfs	Clayey Hapludalfs	Typic

GTP= Gutu Tolera, TUP= Takele Uluma, SBP= Sisay Belete, GKP= Gutama Kuma maize fields

Total base saturation and base saturation percentage

The total base saturation (Mg, Ca, K and Na) and base saturation percentage for surface soil ranged from 10.54 to 17.57 cmol kg^{-1} and 51 to 61 %, respectively for the four maize farm fields (Tables 3 to 6). The base saturation was found in medium range. The percent base saturation for both mid altitude and highland surface soil was greater than 50 %. Wakene (2001) reported similar results.

Cation exchange capacity of the soil

The CEC concentration of the surface soil was 23.52 and 18.55 cmol kg^{-1} GTP-S01 and for TUP-S02, with low sub surface CEC concentration. Similarly, Wakene (2001) found that the CEC of the clay minerals decreased consistently with increasing depth within the profile on the intensively cultivated field. The CEC ranged from 18.55 to 28.84 cmol kg^{-1} soils was low to high range for the four pedons based on (FAO, 1990; and Landon (1991). Similar results reported by Achalu et al. (2012) suggesting soil CEC is expected to increase through improvement of the soil OM content.

Soil classification

The diagnostic surface epipedons and sub-surface of the four soil profile were mollic and agric (Table 7). The soil nomenclatures are presented in Table 8. The soil order of western Showa zone (from Toke Kutaye to Bako-Tibe) is classified as Alfisol USDA soil Taxonomy (SSS, 2006). According to WRB Soil Classification (IUSS Working Group WRB, 2007), the soil is called Nitisol. It is deep, well-drained, red, tropical soils with diffuse horizon boundaries and a subsurface horizon with at least 30 percent. Weathering is relatively advanced but Nitisol are far more productive than most other red tropical soils.

Soil fertility trends of Bako Tibe and Toke Kutaye

Soil pH, CEC, Mg, Ca and clay percentage was non-significant positive association with depth of the soil. Soil organic carbon, total nitrogen, available phosphorous, base saturation percentage had non-significant negative association with increasing depth of the soil (Table 9).Total sulfur had significant negative association with depths of the soil indicating as depth increases total sulfur concentration of the soil decreases. Soil pH had non-significant negative association with total nitrogen and available phosphorous concentration of the soil (Table 9), indicates as pH decreases as amount nitrogen and phosphorous increases in the soil. Significantly higher and positive correlation coefficients of (r = 0.96 and 0.98) between organic carbon with total nitrogen and base saturation percentage (Table 9). This indicated that the higher the organic carbon concentration the higher would be the total nitrogen and base saturation percentage and vice versa. Significantly higher and negative correlation coefficients of (r = -0.88) between organic carbon and clay percentage (Table 9), indicating the higher the organic carbon concentration the lower will be soil clay percentage. There were significant positive association with correlation coefficients of (r =0.91 and 0.94) between total nitrogen and base saturation percentage and clay. Significantly, perfect positive association was obtained between total nitrogen and total sulfur concentration (Table 9). This indicates the higher soil total nitrogen concentration the higher will be base saturation and clay percentage, and total sulfur concentration and vice-versa. Significantly higher positive correlation coefficients of (r=0.97, 0.94 and 0.86) between available phosphorous and silt, sand percentage and total sulfur concentration of the soil. Non-significantly negation correlation coefficients of (r=-0.95) between available phosphorous and clay percentage of the soil. Magnesium had significantly positive association with calcium with correlation coefficients of (r=88) (Table 9), indicating the higher Mg in the soil will be the higher in Ca concentration and vice-versa. Significantly higher negative correlation coefficients of (r=-0.88, -0.87 and -0.95) between clay percentage with silt and sand percentage; and total sulfur concentration of the soil (Table 9). Silt percentage of the soil had higher positive correlation coefficients of (r=98) with sand percentage of the soil (Table 7), indicating the higher the silt percentage will be the higher in sand percentage of the soil and the vice-versa. In conclusion, some soil physicochemical properties had positive and negative relationship with other properties of the soil.

CONCLUSIONS

According to the classification of soils of Bako Tibe and Toke Kutaye Districts of western Showa, Ethiopia, the soils are Alfisol. The surface soils contained higher organic carbon, total nitrogen and available phosphorous. The CEC of the surface soils 23.52 and 18.55 cmol kg^{-1} in Bako Tibe district maize farms field decreased as depth increased; and CEC of 20.06 and 28.84 meq 100 g^{-1} for Toke Kutaye maize farmers field increased with increasing soil depth. Significantly (P = 0.05) perfect positive association was obtained between total nitrogen and total sulfur concentration. Clay percentage had significantly higher negative correlation coefficients with silt and sand percentage and total sulfur concentration of the soil. Continuous intensive cultivation and use of inorganic fertilizers declined soil physic-chemical properties of Alfisol in highland and mid altitude areas of maize farmer's field in western Ethiopia. Soil fertility variations were observed among four pedons of maize farmers' field based on nutrient concentrations. The total N and extractable P status of the soils were found to vary from very low to medium and low to adequate range. There is a need for a more targeted approach soil fertility intervention that differentiates between maize farm field in highland and mid altitude of western Ethiopia. Soil test-based and integrated soil fertility management is recommended for sustainable maize production in highland and mid altitude areas of western Ethiopia.

Table 9. Pearson`s correlation coefficients (r) among selected soil physico-chemical properties of the surface soil of Bako Tibe and Toke Kutaye districts of Western Showa, Ethiopia

	pH (H_2O)	OC	CEC	TN	TP	K	Mg	Ca	PBS	Cl	ST	SD	TS
D	0.59	-0.94	0.35	-0.91	-0.54	-0.65	0.69	0.75	-0.87	0.75	-0.37	-0.39	-0.86*
pH (H_2O)		-0.60	-0.41	-0.78	-0.87	0.16	0.086	-0.011	-0.48	0.84	-0.83	-0.86	-0.77
OC			0.22	0.96*	0.72	0.51	-0.53	-0.71	0.98*	-0.88*	0.57	0.55	0.95
CEC				-0.096	0.41	-0.92	0.30	0.48	-0.32	-0.23	0.62	0.67	-0.075
TN					0.83	0.38	-0.39	-0.52	0.91*	-0.94*	0.68	0.67	0.99**
TP						-0.19	0.025	-0.091	0.68	-0.95*	0.97*	0.94*	0.86*
K							-0.61	-0.73	0.54	-0.057	-0.41	-0.43	0.33
Mg								0.88*	-0.43	0.26	0.089	-.015	-0.29
Ca									-0.70	0.38	0.019	-0.014	-0.45
PBS										-0.83	0.51	0.47	0.92
Cl											-0.88*	-0.87*	-0.95*

D= depth, pH (H_2O) = soil pH, OC=organic carbon, CEC=Cation exchange capacity, TN=Total nitrogen, TP= Total phosphorous, K= potassium, Mg= Magnesium, ca=Calcium, PBS= Percent base saturation, Cl= Clay, ST= Silt, SD=Sand and Ts= Total sulfur.

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