Soil Fertility Characterization and Mapping of Aybra Research Station in Wag-Hemira Ethiopia

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Abstract

Periodic soil characterization and mapping of soil attributes can help to apply appropriate agricultural technologies and effective design of soil fertility management techniques. Therefore, this experiment was designed to characterize, classify and map the soils of Aybra research main station of SDARC in 2015. Three mapping units were identified on the basis of the slope, depth, and texture. In each mapping unit, three representative soil profiles were opened and profile description was made based on the Food and Agricultural Organization (FAO) guidelines. The reference soil group and subgroup classification were finally made based on the FAO World Reference Base for Soil Resources (WRB) international soil classification system. Soil samples were collected from each horizon, prepared and taken to the laboratory for the determination of selected soil physico-chemical properties following the standard procedure. The soils were generally very dark gray to very dark brown. Overall, the soil of Aybra had friable consistency, medium bulk density (1.24-1.39 g/cm^3), subangular to angular blocky structure. The pH (6.9- 7.8) of the soils were neutral to moderately alkaline and low organic matter and total nitrogen. The CEC value of the soil was high to very high and available Phosphorous contents of the surface soil was high to low (12.02-7.29 mg kg^{-1}). Exchangeable Calcium content (9.80-6.60 coml$_c$kg^{-1}) of the surface soil was medium while exchangeable potassium (4.8-2.5 coml$_c$ kg^{-1}) and Magnesium (5.2-3.2 coml$_c$ kg^{-1}) contents were high. The PBS ranges from (35.19-66.37%) and in all profile of studied site was above 35.19% medium to high. The concentration of extractable Zinc (0.43-0.19 mg kg^{-1}) and Copper (1.99-1.37 mg kg^{-1}) were low in surface horizon whereas the concentration of Manganese (20.03-10.64 mg kg^{-}) was medium and Iron (2.81-1.11 mg kg^{-1}) was medium to low. Based on survey and soil analytical data three soil types were identified. Leptic Cambisols, Haplic vertisols and Haplic Leptosols.

Keywords: *Horizon, mapping unit, soil characterization, soil classification, soil fertility*.

Introduction

Soil classification is one of the most important stages in natural resources assessment. Soil fertility assessment through their physical, chemical and biological properties and mapping can help to apply appropriate agricultural technologies and effective design of soil fertility management techniques. Successful agriculture to meet the increasing demands of food, fiber, and fuel from the decreasing per capita land requires the sustainable use of the soil because it is an important non-renewable land resource determining the agricultural potential of a given area. As a result, 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 (Boul *et al.*, 2003). Therefore, soil characterization and classification which provide with knowledge on soil properties are vital in designing appropriate management strategies in agriculture and natural resource for sustainable development.

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 (Aassai and Gebrekidan, 2003). 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 Berhanu, 2006). As regards soil studies, a number of surveys have been carried out for different purposes at different times by different institutions. These surveys cover a sizable area of the country. A detailed survey is necessary to characterize soils at research centers for the proper understanding of the research media and reliable extrapolation of research outcome (Abayneh *et al.*, 2006). Therefore, this experiment was conducted with the objective of characterizing of the soils of SDARC research sites Aybra based on morphological and selected physiochemical properties of the soil.

Material and Methods

Area Description

Sekota Dryland Agricultural Research Center (SDARC) is located in Amhara National Regional State, Wag-Himra Administrative Zone. It is at about 797 Km North West of Addis Ababa. Its geographical extent is 12^{o}

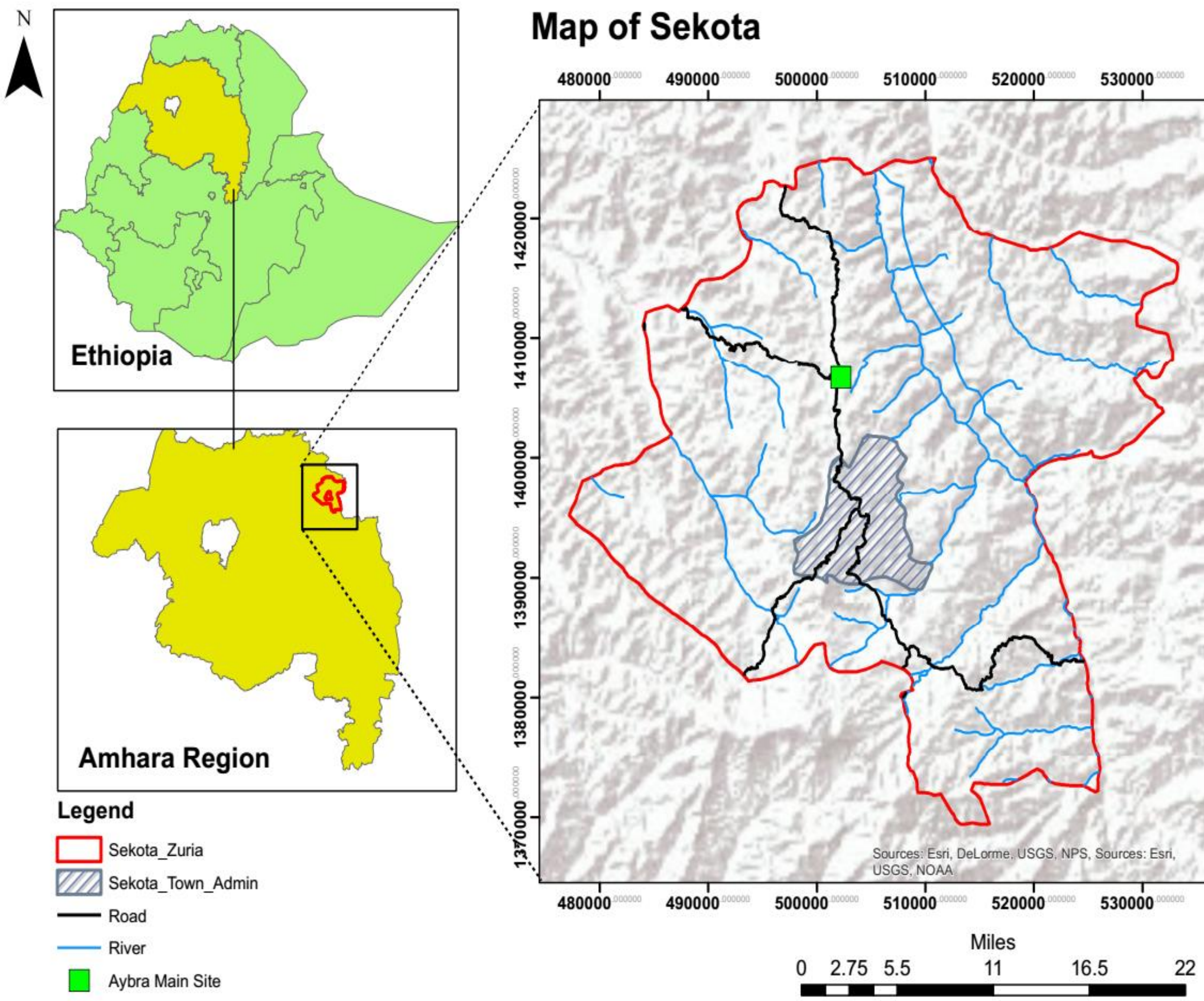

Figure 1. Location map of Aybra main trial site of SDARC

Climate

Five years (20010-2014) data obtained from Kombolcha meteorological station indicates that the study area receives a mean annual rainfall of 769.9 mm. The high amount of rainfall occurring during the main rainy season between July to August (*Kiremt*). The highest rainfall is received in August. Based on 5 years climate data (2009-2013), the mean minimum and maximum annual he time series mean value; the warmer month was found to be June followed by May while the colder month of the time period was January (Figure 2).

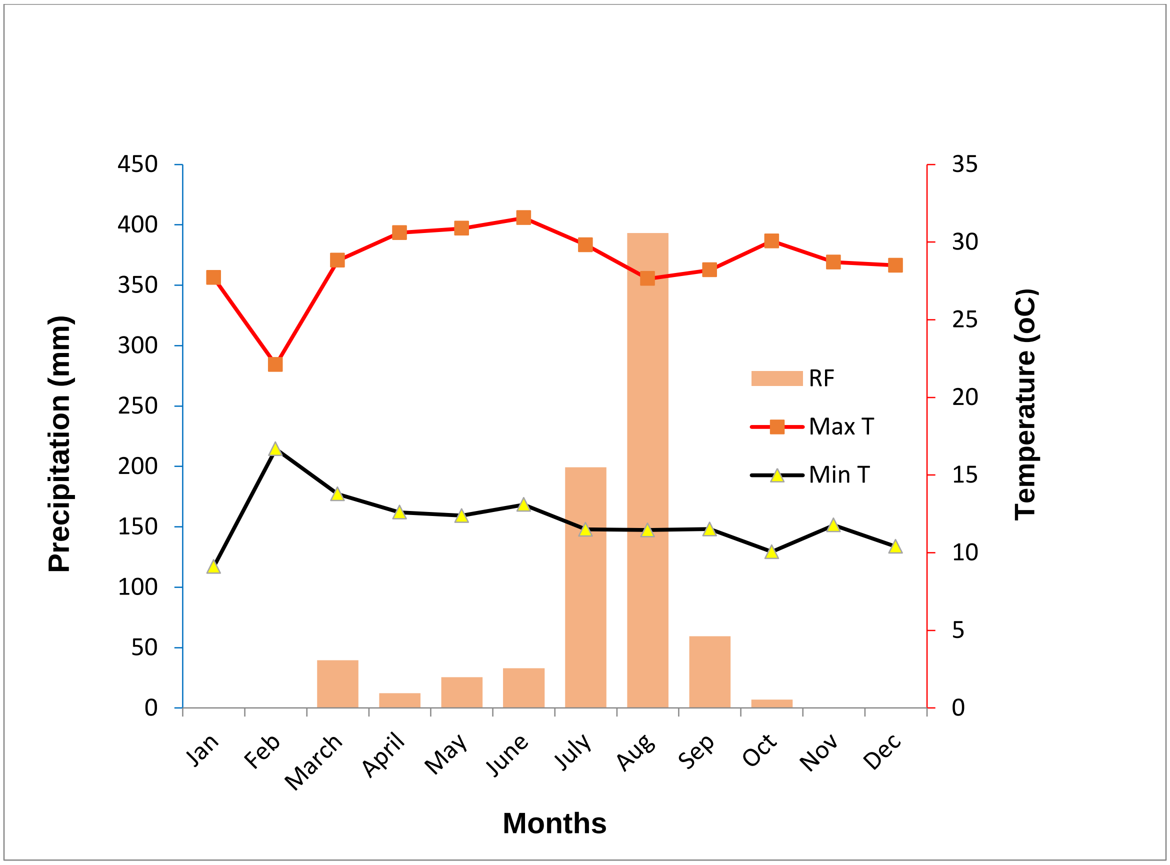

Figure 2. Mean monthly rainfall (2009-2013) and mean monthly minimum and maximum temperatures (2009-2013) of the study area

Field study

In general Auger, observations were made to study land and soil characteristics of the farmland. The augers were made with "Edelman" auger to a depth of 1.2 m unless soil depth is limited or augering is impracticable due to stoniness. The survey technique was a fixed-grid of 50 m by 50 m. In some irregular units, additional observations were made to study the variability. In total 88 auger observations were made (Figure 3). For further soil characterization, 3 soil profile pits (1.5 m width and 2 m length) were dug on representative sites selected based on slope, soil texture, and depth. The soil profile descriptions was made according to (Shand, 2007) system were recorded on the standard form for soil profile description. A total of 7 disturbed and 7 undisturbed (core) soil samples were collected depth wise from each evident genetic horizon for laboratory analysis.

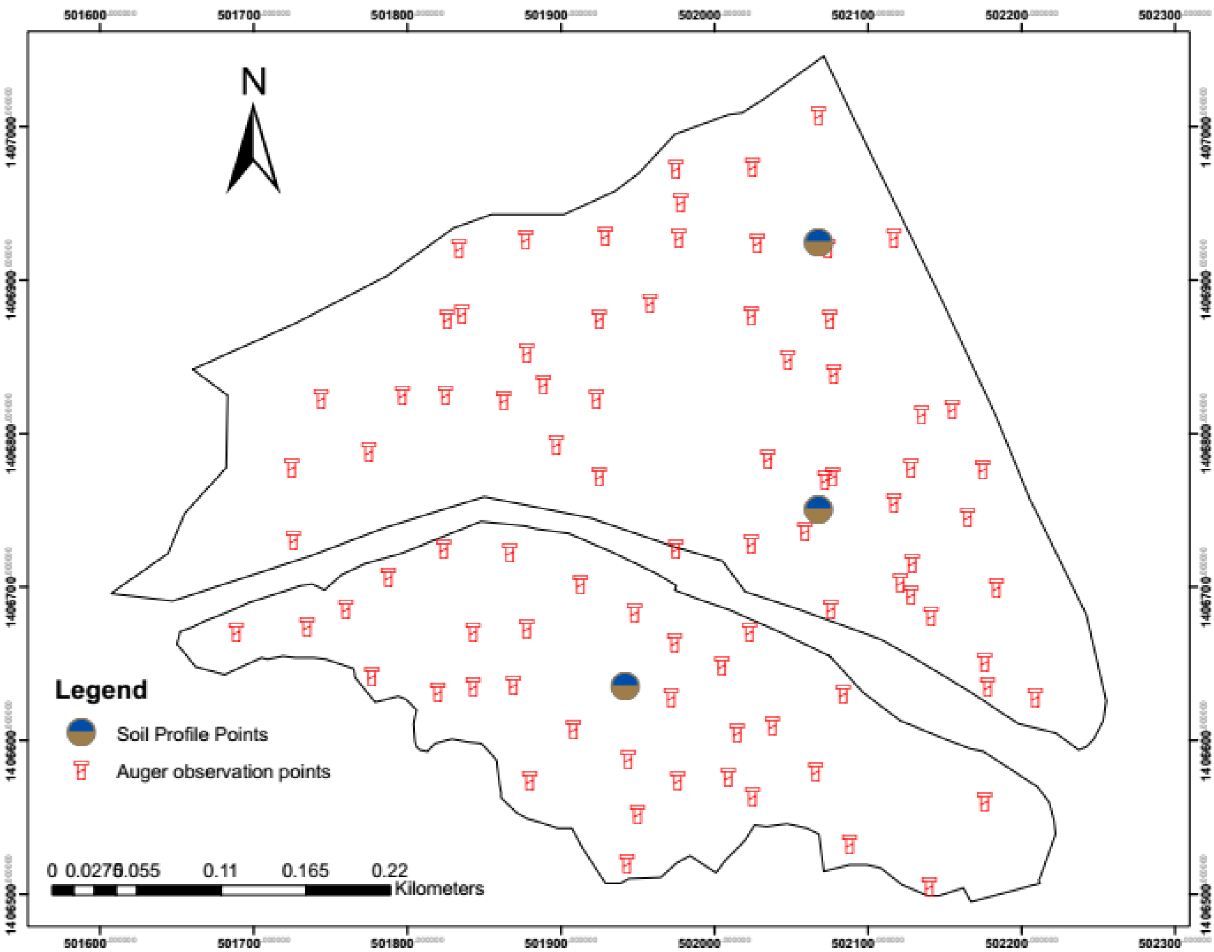

Figure 3. Distribution of auger observation points of the study area

Soil mapping units

Homogeneous land units have been distinguished on the basis of the following three major land/soil characteristics: slope, soil depth, and surface soil texture. Slope percentage in the farm ranges from 0 to 10 and land facets were grouped according to their general slope classes at the first level of generalization. Following, soil depth, as it varies significantly from the farm, was considered to further group homogenous land units of the farm. Land with uniform slope and soil depth was further subdivided on the basis of surface texture. Thus, the soil map of the farm indicates areas that are uniform in slope, soil depth and surface texture (Table 1). In general, 3 different mapping units have been identified (Table 2).

Table 15. Distinguishing criteria of the mapping units

Slope [%]		Soil depth [cm]		Texture [0-20 cm]	
Range	Code	Range	Code	Type	Code
0-3	1	>150	A	Heavy clay	1
3-8	2	100-150	B	Clay	2
8-15	3	50-100	C	Clay loam	3
15-20	4	50-30	D		
<30	5	<30	E	Clay loam	5

Table 2. List of mapping unit identify in Sekota Dry-land Agricultural Research Center

Mapping unit	Profile no.	Slope	Soil depth	Texture	Areas		Soil unit (WRB 2014)
					ha	%	
1a1	2	0-3	>150	Heavy clay	5.02	26.01	Haplic Vertisols
2b2	1	3-8	100-150	Clay	8.31	43.05	Leptic Cambisols
5e4	3	>30	26	Clay loam	5.97	30.94	Haplic Leptosols

Soil Analysis

The soil samples collected from every identified horizon were air-dried and ground to pass through 2 mm sieve. For the determinations of total N and organic carbon (OC), a 0.5 mm sieve was used. Analysis of the physicochemical properties of the soil samples was carried out following standard laboratory procedures. Bulk density was determined using the core-sampling method (BSI, 1975). Particle size distribution was analyzed by using the ratio method. Soil pH was determined in H_2O using 1:2.5 soils to solution ratio using a combined glass electrode pH meter (Carter and Gregorich, 2006),

Total N was analyzed by the Kjeldahl digestion and distillation procedure (Bremner and Mulvaney, 1982), whereas OC was determined following the wet combustion method of Walkley and Black as outlined by Van Ranst *et al.* (1999). The available phosphorus was determined using the standard Olsen extraction method (Olsen *et al.*, 1954). Extractable micronutrients Fe, Mn, Zn, and Cu were extracted from the soil samples with Diethylene Triamine Pentaacetic Acid (DTPA) as described by Lindsay and Norvell (1978). All the micronutrients extracted were measured by atomic absorption spectrometry (AAS). As it is mentioned in Annex, the soil nutrient level classifications and ratings were made based on (Cottenie, 1980; Tekalign *et al.*, 1991; Jones, 2002; Jahn *et al.*, 2006; Hazelton and Murphy, 2016). Finally, analysis of simple correlation coefficient among the different soil physical and chemical properties were carried out using SAS (1997) software to reveal the magnitude and direction of relationships between each other.

Result and Discussion

Physico-chemical Characteristics of the Mapping Units

Mapping unit 1a1

This unit refers to moderately sloping and had deep and moderate deep soil. The soil pedon has subsurface sandy loam texture, evidence of change in soil structure from weak fine granular to moderate medium sub-angular in the subsoil, it covers 8.31 ha or 43.05% of the farm. The soil color dark brown (7.5 YR3/4) in color when dry and moist. The texture is varied from clay loam silt clay loam. These soils have a consistency that is friable when moist and plastic to very plastic when wet. The pH of surface soil is 6.9, increasing to 7.1 in subsurface horizons and the electrical conductivity ranges between 0.15 and 0.27 ds/m surface to subsurface respectively. The cation exchange capacity of the soils is a range as medium (25.2 to 32.64 cmol (+)/kg soil) and its percentage base saturation ranges from 41.69 to 66.37%, increasing with depth. The organic matter and total nitrogen content decrease with depth and their values range from 0.34 to 1.55% for organic matter and 0.011 to 0.028 % for total nitrogen; while available phosphorous is low which ranges (4.98 to 8.10 ppm). Available exchangeable cations range between 9.4 to 7 cmolc kg^{-1} for Ca, 5.0 to 3.4 cmolc kg^{-1} for Mg, 4.8 to 2.60 for K and 0.63 to 0.14 for Na. Available micronutrients range between 2.81 surface horizon to 7.29 mg kg^{-1} subsurface horizon for Fe, 23.03 mg kg^{-1} surface to 6.41 mg kg^{-1} subsurface horizon for Mn, 0.36 mg kg^{-1} to 0.97 mg kg^{-1} surface to subsurface horizon respectively for Zn and 1.99 mg kg^{-1} to 0.48 mg kg^{-1} for Cu.

Mapping unit 2b2

This mapping unit refers to those located in flat and gently sloping areas as compared with others and had very deep soil. It covers 5.02 ha or 26.01% of the farm of the research center. The soil of mapping unit had soil color (dry) of very dark gray (7.5YR3/1) to brownish yellow (10YR6/6 whereas color in moist ranging from very dark gray (7.5YR 3/1) to dark brown (7.5YR 3/4) in surface soil. The dry color pattern of subsurface soil color varied from very dark grayish brown (10YR3/2) to very pale brown (10YR7/3) whereas, the moist color ranged from dark brown (7.5YR3/2) to brown (7.5YR5/3). Consistency of the surface horizons was from hard to slightly hard when dry, friable to very friable when moist, very sticky to sticky and very plastic to slightly plastic when wet at surface horizons. On the other hand, the subsurface horizons had slightly hard to very hard when to dry very friable to losses when moist, very sticky to slightly sticky and plastic to slightly plastic when wet consistency. The textural class was clay (43.1%). The pH of surface soil is 6.9 increasing to 7.8 in subsurface horizons and the electrical conductivity ranges between 0.15 mS/cm surfaces to 0.22 mS/cm subsurface. The cation exchange capacity of the soils was high in the surface horizon whereas high to very high in subsurface horizon. The organic matter ranges from 1.55 to 1.48 % surface to subsurface and total nitrogen content ranges from 0.076 to 0.038 surface to subsurface; while available phosphorous is medium to low (12.02 to 7.66 ppm). The exchangeable cation ranges from 6.6 to 11.0 for Ca, 3.20 to 6.80 for Mg, 2.5 to 2.58 for K, 0.65 to 0.83 for Na in surface to subsurface. Available micronutrients range between 1.89 to 2.03 ppm for Cu, 0.43 to 0.13 for Zn, 10.64 to 7.43 for Mn and 1.91 to 1.10 for Fe from the surface to subsurface horizon.

Mapping unit 5e4

This mapping unit is located in steep and gentle slopping as compared with other mapping units and had shallow soil depth. It covers 5.97 ha or 30.94% of the farm of the research center. The soil of mapping unit had soil color (dry) of brownish yellow (10YR6/6) to dark brown (7.5YR3/4 when moist in surface soil respectively. Consistency of the surface horizons was from hard to slightly hard when dry, friable to very friable when moist, very sticky to sticky and very plastic to slightly plastic when wet at surface horizons. On the other hand, the subsurface horizons had slightly sticky to slightly plastic when to wet and very friable to slightly hard when too moist to dry respectively. The textural class was clay loam. The pH of surface soil is 6.9 in subsurface horizons and the electrical conductivity was 0.25 dS/cm surfaces horizon. The cation exchange capacity of the soils was 32.48 in the surface horizon. The organic matter of the surface horizon of the mapping unit was 0.97 % and total nitrogen content was 0.028 in the surface horizon; while available phosphorous is low (7.29 mg kg^{-1}). The exchangeable cation for Ca was 9.80 cmolc kg^{-1}, for Mg 5.20 cmolc kg^{-1}, for K 2.52 cmolc kg^{-1} and for Na 0.8 cmolc kg^{-1} was recorded in the surface horizon. Available micronutrients Fe was 1.11 mg kg^{-1}, Mn was 11.12 mg kg^{-1}, for Zn 0.19 mg kg^{-1} and for Cu 1.37 mg kg^{-1} was recorded in the surface horizon.

The overall soil physico-chemical properties

Soil color

The surface horizon color (dry) varied from very dark gray (7.5YR3/1) in profile 2 to brownish yellow (10YR6/6) in profile 3. Similarly, color (moist) ranged from very dark gray (7.5YR 3/1) in profile 2 to dark brown (7.5YR 3/4) in profile 1. The dry color pattern of subsurface soil color varied from very dark grayish brown (10YR3/2) to very pale brown (10YR7/3) whereas, the moist color ranging from dark brown (7.5YR3/2) to brown (7.5YR5/3). Surface layers had darker color as compared to the subsurface horizons within each pedon. Dark colored surface horizons (values < 3) are often enriched with OM, offering many benefits to the soil this is attributed to the effect of relatively higher OM content in the surface horizons compared to the subsurface of the soil (Table 1). Many authors reported that the surface horizons have a darker color than the corresponding subsurface horizons as a result of relatively higher soil OM contents (Mulugeta and Sheleme, 2010; Dengiz *et al.*, 2011; Yitbarek *et al.*, 2016).

Soil consistency

The consistency of the surface horizons was varied from hard to slightly hard when dry, friable to very friable when moist, very sticky to sticky and very plastic to slightly plastic when wet at surface horizons (Table 3). On the other hand, the subsurface horizons had slightly hard to very hard when to dry very friable to losses when moist, very sticky to slightly sticky and plastic to slightly plastic when wet consistency. Very sticky and very plastic consistency indicates relatively high clay content could be the change in consistency from the surface to subsoil horizons reflects high contents of clay and low contents of organic matter in subsoil horizons. The result is similar to Mohammed and Solomon (2010) indicated that the consistency of the soil is affected by soil texture. The overall friable consistency of the soils indicates that the soils are workable at appropriate moisture content.

Soil structure

The soil structure varied from subangular blocky, angular sub-blocky and blocky angular structure in their surface horizons pedon 1, 2 and 3 respectively. Subsurface horizon structure ranges from granular to blocky angular. The structure variation is might be due to clay content. The result is concurrent with findings of (Ashenafi *et al.*, 2010) who reported that higher clay content could be a reason for the better development of soil structure.

Table 3. Morphological properties of the soil Aybra research site

Horizon	Depth [cm]	Color		Structure			Consistency				Horizon boundary
		Dry	Moist	Grade	Size	Shape	Wet		Dry	Moist	
							Stickiness	Plasticity			
Profile-1											
	0-30	7.5YR3/4	7.5YR3/4	MO	ME	SB	ST	PVP	HA	FR	C S
	30-85	5YR4/4	5YR3/4	WE	FI	GR	SST	SPL	SHA	VFR	A S
	85-105	10YR4/6	7.5YR4/4	WE	FI	GR	SST	PL	SO	VFR	D S
	105-145	10YR5/4	7.5YR3/4	WE	FI	GR	NST	NPL	LO	LO	--
Profile- 2											
Ap	0-30	7.5YR3/1	7.5YR3/1	ST	CO	AS	VST	VPL	VHA	FR	D S
AB	30-155	10YR3/2	7.5YR3/2	VST	CO	AB	VST	PL	VHA	FR	--
Profile-3											
Ap	0-26	10YR6/6	7.5YR3/4	MO	ME	AB	SST	SPL	SHA	VFR	C S

Consistence: SO = soft, SHA = slightly hard, HA = hard, VHA = very hard, LO = loose, VFR = very friable, FR = friable, NST = non-sticky, SST = slightly sticky, ST = sticky, VST = very sticky, NPL = non-plastic, SPL = slightly plastic, PL = plastic, PVP = plastic to very plastic.

Structure: WE = weak, MO = moderate, ST= strong, VST = very strong, CO = coarse, ME = medium, FI = fine, SB = sub-angular blocky, AS=angular and sub angular blocky GR = granular, AB = angular blocky. Horizon Boundary C=clear, G=gradual, D=diffuse, S=smooth.

Particle size distribution

The texture class of the surface horizon varies from loam to clay loam in all profiles (Table 4). The soil at slope 3-8 % had relatively higher clay content (30.2 - 43.1 %) in profile 2. This indicates that finer textures became from the upper slope which may be due to the removal of fine soil particles from steeper slope positions by water erosion. On the other hand, the subsurface horizon textural class ranged from loam, clay loam, and clay. This indicates that finer from the upper slope which may be due to the removal of fine soil particles from steeper slope positions by erosion.

Table 4. Selected Physical Characteristic of The Soils of Aybra Site.

Horizon	Depth(cm)	Sand %	Silt %	Clay %	Textural class	BD g cm^{-3}	TP
Profile 1							
	0-30	37.7	31	31.3	CL		
	30-85	51.16	23.83	25	SCL		
	85-105	35	28.7	36.3	CL		
	105-145	35.54	43.91	22.53	L		
Profile 2							
Ap	0-30	23.5	33.4	43.1	C	1.24	53.20
AB	30-155	40.7	29.1	30.2	C	1.25	52.83
Profile 3							
Ap	0-26	19.5	19.1	36	CL	1.39	47.54

Note: C = clayey, CL = clay loam, SCL = sandy clay loam, BD = bulk density, PD = particle density, TP = total porosity

Bulk and total porosity

The bulk density of the surface horizons varied from 1.25 g cm^{-3} to 1.39 g/cm^{-3} with relatively low to high value and the subsurface horizon ranged from 1.22 to 1.35 g/cm^{3}. The result shows that bulk density increases with increasing depth. The difference in bulk density between surface and subsurface layers might be due to organic matter variation within the depth. The result is concurrent with Ahmed Hussein (2002) and Fisseha and Gebrekidan (2007) who reported that the lowest bulk density was found at the surface horizon. The increasing bulk density with the profile depth is due to low organic matter which is 0.34 % at profile 1 and 1.48 at profile 2. According to Landon (2014), for good plant growth bulk densities should be below 1.4 g/cm^{3} this implies that no excessive compaction and no restriction to root development.

Total porosity

The total porosity (TP) of the soil was from 47.54 to 54.99% in the surface profile 3 and 1, respectively. Total porosity was decreased with increasing soil depth. The surface horizons had relatively higher total porosity than the underlying subsurface horizons. This might indicate low organic matter content were at the subsurface of horizons as compared with the top layer of the soil horizon. The result is in line with the finding of Dereje, (2013) and Alem (2014) who reported that the lower total porosity in the subsurface of the soil layer a result of low OM content and high bulk density. Brady *et al.* (2008) confirmed that reduction of total porosity with depth wise is associated with decreasing with organic matter content.

Table 5. Selected chemical characteristics of soils of Aybra

Horizon	Depth (cm)	pH (1:1.25)	EC (ds/m)	TN [%]	OM [%]	Av.P mg kg^{-1}
Pedon 1						
	0-30	6.9	0.15	0.028	1.55	8.10
	30-85	6.7	0.27	0.028	1.18	5.62
	85-105	7.1	0.2	0.018	1.38	5.46
	105-145	6.8	0.16	0.011	0.34	4.98
Pedon 2						
Ap	0-30	6.9	0.15	0.076	1.55	12.02
AB	30-155	7.8	0.22	0.038	1.48	7.66
Pedon 3						
Ap	0-26	6.9	0.25	0.028	0.97	7.29

Soil pH

Soil pH (H_2O) of the surface ranges from 6.9 in profile 1 and 2 to 6.7 in profiles 3 (Figure 4). Whereas the pH (H_2O) of the subsurface horizon was varied from 6.7 to 7.8. Based on Tekalign *et al.* (1991) soil pH rating, the value of surface and subsurface soil horizon of the study area was within neutral to slightly alkaline class (Table 5). Increasing pH value in profile 1 and 2 with increasing depth may be indicated the presence of vertical movements of exchangeable cations, which released from the decomposition of organic matter. Similarly, decreasing organic matter content with increasing depth was concurrent with findings of Ayalew and Beyene (2012) and Dereje (2013).

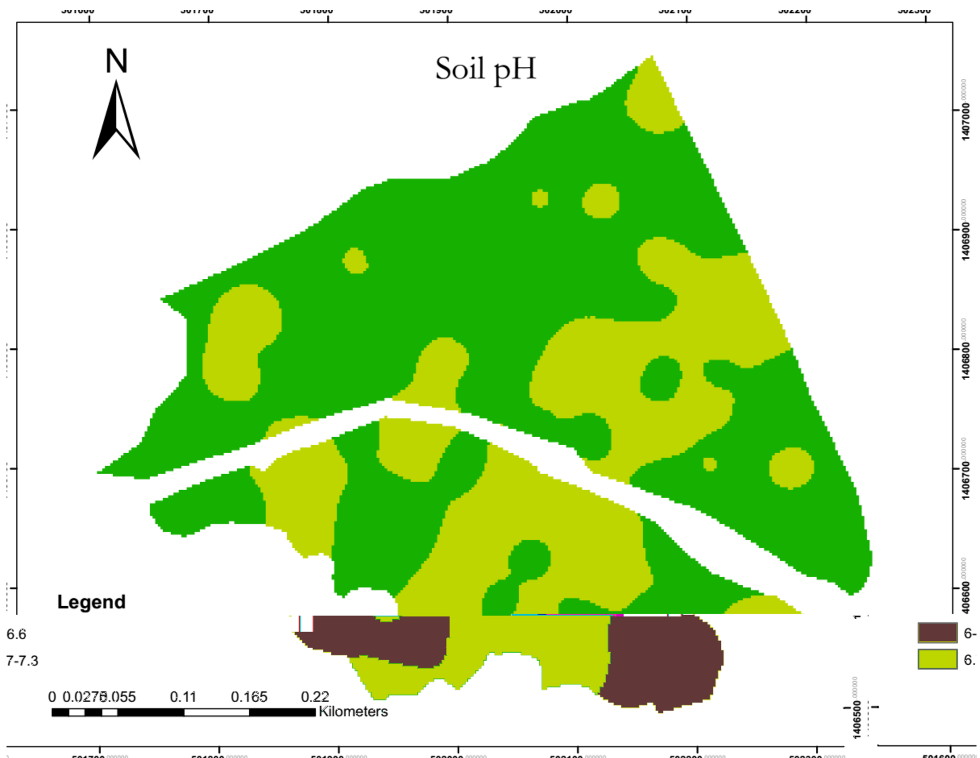

Figure 4. The distribution of P^{H} value

Electrical conductivity

Electrical conductivity (EC) of the surface and subsurface horizon ranged from 1.5 ds/m in profile 1 and 2 to 1.6 ds/m to 2.7 ds/m surface and subsurface horizons respectively (Table 5). According to low EC value in all the land units in the present study indicate a non-saline condition despite the aridity of the climate and limited rainfall to leach away base-forming cations from the surface soil in the area in general and the study site in particular. low EC value in all the land units in the present study indicate a non-saline condition despite the aridity of the climate and limited rainfall to leach away base-forming cations from the surface soil in the area.

Soil organic matter

The organic matter content in surface horizons of the soil ranged from 1.55 % in profile 1 and 2 to 1.51% in profile 3 while, in the subsurface horizon it varies from 0.38 % in profile 1 to 1.48 in profile 2, the organic matter content variation decreases within depth in profile 1 and 2 (Figure 5). The result is similar to Feyissa *et al.* (2006) and Dereje (2013) indicated that the surface horizon showed higher OM than the subsurface. Ayalew and Beyene (2012) reported that the content of organic matter decreases with increasing depth. According to organic matter, the rating is given by Tekalign (1991) organic matter contents 0.86-2.59 is low so, the organic matter content of all studied profile was low organic matter. This might be the fact that the cultivated land soil have low organic matter than uncultivated land of forest lands (Forth, 1990). The result is concurrent with (Alem *et al.*, 2015; Chekol and Mnalku, 2012; Mohammed and Solomon, 2010) reported that the value is similar to most of the cultivated soils of Ethiopia, which have low organic matter content which is attributed to land use histories such as complete removal of biomass from the field and rapid rate of mineralization.

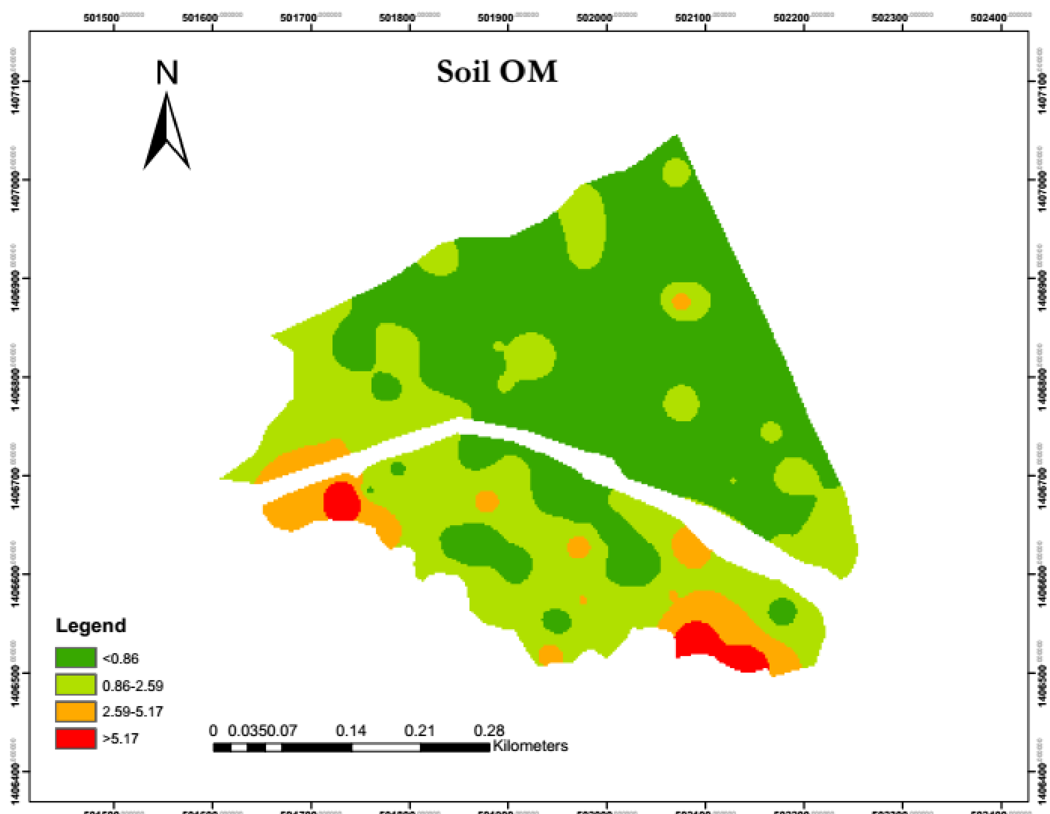

Figure 5. Organic Matter Distribution

Total Nitrogen

Total nitrogen content of the soil surface horizons ranges from 0.028 in profile 1 and 3 to 0.078 in profile 2. In the subsurface horizons, it ranges from 0.011 in profile 1 to 0.038 in profile 2 (Figure 6). According to total nitrogen, the rating is given by Tekalign (1991) total nitrogen content between 0.01 to 0.12 is low. Hence the total nitrogen content of the studied profile was low. The presence of very low total nitrogen in all profiles could be as a result of variation in the amount of organic matter available in the soil. Ashenafi *et al.* (2010) reported that intensive and continuous cultivation aggravated OC oxidation, resulting in a reduction of total N as compared to virgin land.

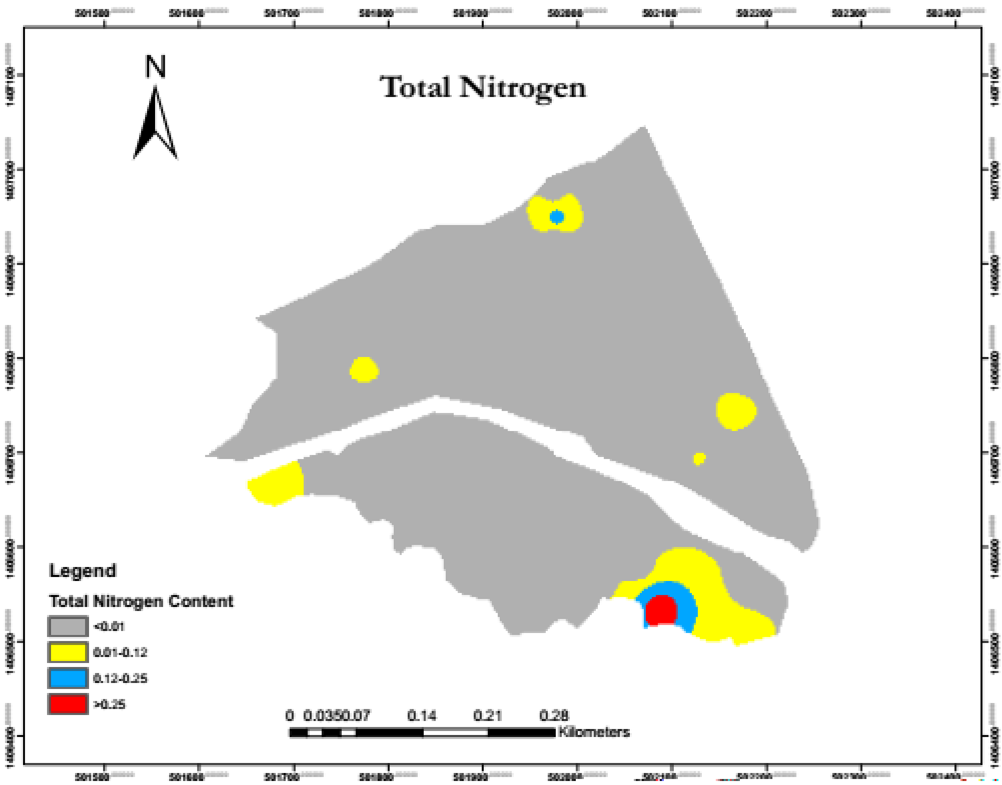

Figure 6. Total Nitrogen Distribution

Available phosphorus

The available phosphorus contents extracted by the Olsen method were medium in all surface horizons except in profile 2 which was high (Table 5). The available phosphorus contents in the surface horizons ranged from 12.02 mg kg^{-1} to 7.29 mg kg^{-1}. Whereas the available phosphorus contents in the subsurface horizons ranged from 7.66 mg kg^{-1} to 4.98 mg kg^{-1}. Available P decreased with the profile depths this result is in agreement the finding of Ashenafi *et al.* (2010) and Alem (2014) who reported that highest amount of Av. P contents of the soil was recorded in the surface horizon. The highest amount of Av. P contents of the soils in the surface horizons of all soil profiles as compared to subsurface horizons could be attributed to the difference in organic matter contents of the horizons. According to the rating set by Olson (1954) available P observed in all surface horizons are categorized as low to high levels.

Table 6. Exchangeable cation CEC, Sum of bases, PBS and ESP of Aybra main trial site

Exchangeable cation (cmolc kg-1)							
Horizon	Depth (cm)	Ca	Mg	K	Na	CEC	PBS %
Profile 1							
	0-30	9.40	5.00	4.80	0.63	29.88	66.37
	30-85	7.00	3.40	2.62	0.57	32.6	41.69
	85-105	9.60	4.80	2.69	0.21	32.64	53.00
	105-145	7.60	3.60	2.60	0.14	25.2	55.32
Profile 2							
Ap	0-30	6.60	3.20	2.50	0.65	36.8	35.19
AB	30-155	11.00	6.80	2.58	0.83	40	53.03
Profile 3							
Ap	0-26	9.80	5.20	2.52	0.8	32.48	56.40

Cation exchange capacity

The surface horizon soil had high CEC values which ranged from 29.88 to 36.8 $coml_c$ (+) kg^{-1} of soil, whereas the subsurface horizon the level of CEC was high to very high which ranges from 25.2 to 40 $coml_c$ (+) kg^{-1} (Table 6). According to Landon (2014), CEC values are rated < 5 as very low, 5 - 15 as low; 15 - 25 as medium, 25 - 40 as high and > 40 as very high. The high value of CEC in the study soil might be indicated that presence of high clay accumulation. The result is similar to Hussein and Gebrekidan (2002) and Kibret and Hagos (2014) reported that higher CEC values, as a result, the nature of clay and amount of clay accumulation.

Exchangeable bases

The highest exchangeable Ca value was recorded in the surface horizon of Profile 3 (9.8 cmolc kg^{-1}) followed by Profile 1 (9.4 cmolc kg^{-1}), whereas the lowest was obtained in the surface horizon of Profile 2 (6.60 cmolc kg^{-1}) (Table 6). Similarly, the exchangeable values of Ca in the subsurface horizons were higher in profile 2 (11.00 cmolc kg^{-1}) compared to other profiles. The distribution of exchangeable calcium in subsurface horizons shows inconsistency in the studied profiles 1. This could be due to the presence of Ca bearing parent materials at the site of soil sampling that has contributed much to the high exchangeable Ca contents on the soil exchange complex. According to rating set by Shand (2007) the concentration of exchangeable Ca observed in all surface horizons are categorized as medium levels and the concentration exchangeable Ca of subsurface horizon are categorized as high (profile 2) to medium level.

On the other hand, the distribution of exchangeable Mg in subsurface horizons shows inconsistency in the studied profiles 1. The highest exchangeable Mg value was recorded in the surface horizon of Profile 3 (5.20 cmolc kg^{-1}) followed by Profile 1 (5.00 cmolc kg^{-1}), whereas the lowest was obtained in the surface horizon of Profile 2 (3.20 cmolc kg^{-1}). Similarly, the exchangeable values of Mg in the subsurface horizons were higher in profile 2 (6.2 cmolc kg^{-1}) compared to other profiles. According to Shand (2007) the concentration of exchangeable Mg observed in all profile are categorized as high level. The highest exchangeable Na in surface horizon ranged from 0.8 cmol kg^{-1} in Profile 3 to 0.65 cmol kg^{-1} in Profile 2, while in the subsurface horizon exchangeable Na ranges from 8.3 cmol kg^{-1} in profile to 0.57cmol kg^{-1} in profile 1. The concentration of exchangeable Na observed in all profile is categorized as very low level (Shand, 2007). The highest exchangeable K content in the surface horizon ranged from 4.8 cmol kg^{-1} in Profile 1 to 2.52 cmol kg^{-1} in Profile 2. Whereas in subsurface horizon exchangeable K content varies from 2.69 cmolc kg^{-1} in profile 1 to 2.58 cmolc kg^{-1} in profile 2. The concentration of K in surface and subsurface categorized as in very high rang level in all profiles (Shand, 2007). The percent base saturation (66.37) was found to be highest in the surface horizon of profile 1, whilst the lowest (35.19) was recorded in the surface horizon of profile 2. Highest percentage base saturation in the subsurface (55.32) was found in profile 1 and the lowest was found in 41.69 in profile 1. In general percentage base saturation of the experimental site was above 35.19 in all profile studies.

Micronutrient

The micronutrients contents in pedons 2 decreased with increasing soil depth and also Mn and Cu in pedon 1 decreased with increasing soil depth but, Fe and Zn showed an unsystematic pattern with increasing depth in Pedons 1. Highest Fe (2.81 mg kg^{-1}) and the lowest (1.11 mg kg^{-1}) was registered in the surface horizon of Profiles 1 and 3, respectively, whereas in the subsurface horizons it is varied from 7.29 mg kg^{-1} (Profile 1) to 0.98 mg kg^{-1} (Profile 1) (Table 7). In general, extractable Fe in the surface, as well as the subsurface horizons, shows variation in all studied profiles. According to the interpretative values of DTPA extractable micronutrients set by Jones (2002), all the soils of the study area were rated as low to high in their extractable Fe contents surface and subsurface horizon.

Table 7. Available micronutrient contents of soils of the study area

Micronutrient (mg kg^{-1})					
Horizon	Depth (cm)	Fe	Mn	Zn	Cu
Profile 1					
	0-30	2.81	23.03	0.36	1.99
	30-85	0.98	17.71	0.97	0.9
	85-105	7.29	6.41	0.34	0.48
Profile 2					
Ap	0-30	1.91	10.64	0.43	1.89
AB	30-155	1.10	7.43	0.13	2.03
Profile 3					
Ap	0-26	1.11	11.12	0.19	1.37

The highest concentration of extractable Cu was observed (1.99 mg kg^{-1}) in the surface horizons of Profile 1 and the lowest (1.37 mg kg^{-1}) in Profile 3. In subsurface horizons concentration of available Cu ranged from 2.03 mg kg^{-1} in Profile 2 to 0.48 mg kg^{-1} in Profile 1. The depth wise distribution pattern of Cu in Profiles 1 decreased with soil depth, but in the profile 2 increases with increasing depth. According to nutrient critical value levels suggested by Jones (2003) the studied micronutrient level was below at the critical level in all profile. Highest Mn (23.03 mg kg^{-1}) and the lowest (10.64 mg kg^{-1}) was registered in the surface horizon of Profiles 1 and 2, respectively, whereas in the subsurface horizons it is varied from 17.71 mg kg^{-1} (Profile 1) to 6.41 mg kg^{-1} (Profile 1). Extractable Mn in the surface horizons profiles 2 and 3 did not show variation. All the soil samples were rich in Mn, when compared with the critical levels. A highest (0.43 mg $kg\text{-}^{1}$) concentration of extractable Zn was observed in the surface horizons of the Profile 2 and the lowest (0.19 mg $kg\text{-}^{1}$) in Profile 3. In subsurface horizons concentration of extractable Zn ranged from 0.97 mg kg^{-1} in Profile 1 to 0.13 mg kg^{-1} in Profile 2. The lower value observed in all Profile due to slope positions that the topsoil removed by erosion. The depth wise distribution pattern of Zn in profiles 1 did not follow a specific trend. According to the rating set by Jones (2003) the available Zn was in the range of very low to medium in surface and subsurface horizon of studied profiles.

Conclusions and Recommendations

The study was conducted in SDARC main research site of Aybra in wag-himra zone. The result from the field survey and laboratory analysis revealed that three major soil types namely, Cambisols, Leptosols, and Vertisols were identified. The soils were relatively varied in morphological, physical and chemical characteristics. The color of most of the surface soils varied from brownish yellow (pedon 3 which is in the steep slope) to very dark gray (pedon 2 medium slopes). The friable consistency, medium bulk density (1.24 - 1.39 gm/cm^3), subangular to angular blocky structure, indicate that the soils have good physical condition for plant growth. The pH-H_2O of the soils was slightly acid to neutral in the surface soil but in the subsurface soil, it varies from slightly acidic to moderately alkaline. Electrical conductivity values of the surface and subsurface soils ranged from 1.5 to 2.5 ds/m in profile 1 and 3 to1.6 to 2.7 ds/m in profile 1 and 2 in the subsurface. The OM values varied from 0.97% to 1.5% and 0.38% to 1.5% in surface and subsurface horizons respectively. The total nitrogen (TN) content was low to very low while the organic matter (OM) content was low to moderate in most soil types. The concentration of exchangeable Ca observed (9.80-6.60 coml$_c$ kg^{-1}) in all surface horizons are categorized as medium. The exchangeable potassium (4.8-2.5 coml$_c$ kg^{-1}) and Magnesium (5.2-3.2 coml$_c$ kg^{-1}) in all profile surface horizon were at a high level. The PBS ranges from (35.19-66.37%) and in all profile of studied site PBS was above 35.19%.

Extractable iron (Fe) in the soils ranged from 2.81 to1.11 mg kg^{-1}, while extractable Mn ranged from 23.03 to 10.64 mg kg^{-1} in the surface horizon. On the other hand, the contents of extractable copper (Cu) in the soils ranged from 1.99 to 1.39 mg kg^{-1}, while extractable Zn ranged from 0.43 to 0.19 mgkg^{-1}. Surface and subsurface horizon of the study area was characterized by low extractable micronutrient contents. Based on the result, Aybra soils have low organic matter content and it should be maintained with integrated soil fertility management (application of manure, artificial fertilizer, and incorporation of crop residues). Different conservation measures should be in place in the steep slope areas of the site to minimize erosion. Continuous and proper management of the degraded areas of the site should be made through physical and biological soil conservation measures. Fertilizers recommendation/application should be crop-soil-site specific.

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