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Characterization of soils of Jello Chancho Watershed: The case of Liban District, East Shewa Zone Ethiopia

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Understanding of soil-physicochemical properties is necessary for appropriate utilization of soil resources. Soil resources characterization and classification are major requirements. In view of this, a study was conducted on soils of Jello-Chancho Watershed to characterize physicochemical properties of the soil. To achieve these objectives, three profiles were opened from the watershed and examined for their selected physicochemical properties. The soils were generally pinkish white to black color. The structure was granular in the surface horizons of all profiles while friable consistence in moist basis of surface horizons in all profiles. Textural classes were ranged from loam to clay whereas bulk density ranged from 0.90-1.18gcm-3, and total porosity ranged from 55.47-66.00%. The soils were rated as moderate acid to neutral. The EC was low in all studied profile. The OM contents in the study area ranged from 1.93-4.47% and TN contents ranged from 0.10-0.23%. Av. P was ranged from 0.02-3.86mgkg-1. The exchangeable potassium, calcium and magnesium were high to very high in all studied profiles while sodium was very low to high. CEC of the study soils were ranged from 18.90-68.20cmolckg-1 whereas percent base saturation ranged from 53-98%. The soils were classified as Abruptic-Luvisols (Profile-1), Haplic-Luvisols (Profile-2) and luvic-Phaeazems (Profile-3), respectively. The morphological and physiochemical properties of the soil for the study area change with topography and soil depth. Low level of OM, available P, total N, and exchangeable Na could be the major problems in the study area. The control of such damaging effects would require proper soil conservation strategies.

Key words: Classification, horizon, morphological properties, profile, soil physico-chemical properties, topography.

INTRODUCTION

Soil is a slowly renewable natural resource that determines the sustainability of agricultural system. Land use, water movement, and vegetation productivity have relationships with soil. Soils provide food, fuel and fodder for meeting the basic animals and human needs (Kedir, 2015). But, due to the increasing rate of population demanding food, the nutrients have been depleted and the productive capacity of soils has diminished through changes in its characteristics. This may require systematic evaluation of soil resources in respect to their status, characteristics, distribution, and use potential, which is useful for developing an effective land use system for

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enhancing agricultural production on a sustainable basis (Pulakeshi et al., 2014). Therefore, knowledge of soils in respect of their formation, nature, origin, properties and distribution becomes available to realize sustainable agriculture. Such information is also useful for foresters, engineers, land-use planning and soil management. Additionally, right land management requires sound information on management options, which can be used for the optimization of land use for competing demands (Mohammed, 2003). The protection of the soil itself requires more information about its characteristics and dynamics (Feyissa and Gebrekidan, 2006). Success in soil management to maintain soil quality depends on the understanding of how soils respond to agricultural use (Negassa, 2001). This indicates that understanding the properties of soils is prerequisite for designing appropriate management strategies thereby solving many challenges that the Ethiopians are facing in the crop and livestock production sectors and in their efforts towards natural resource conservation and management for sustainable development.

Agriculture is the major economic activity in Ethiopia. Thus, there is an increasing demand for information on soils as a means to produce food and fodder (Fasina, 2004). Some information is necessary to create purposeful soil classification scheme and identify soil fertility status in order to mitigate some sole soil problem in an ecosystem (Mohammed et al., 2017*).* On the other hand, Ethiopia has different soil resources largely because of its different topography, geology and climatic conditions. Due to these higher variations of soil, regional and sub-watershed studies seem to be insufficient in providing basic soil data that can help to manage soils according to the local variability. Soil survey reports by FAO (2014) have indicated that soil conditions show some variations across the regions and due to that, different soils require specific management practices. Hence, characterization of soils in some parts of the country could not be enough to make development planning at country/regional level because of the variability of the soil within place. Therefore, sustainable soil management practices that are based on the understanding of soil system are not available for most parts of the country. Therefore, there is a need to launch detailed soil characterization works in Ethiopia. It also gives information to agricultural experts, policy makers, engineers and foresters for understanding of the physical, chemical and mineralogical properties of the soils. In addition, it can help to determine the types of vegetation and land use best suited to a location. Thus, soil characterization study is a major building block for understanding the soil, classifying it and getting the best understanding of the environment (Kassa and Kibret, 2013).

Furthermore, in Oromia Region like Liban district, there is inadequate information on soil properties and soil fertility status. Specifically, in the study area the major soil type is not known unless the local people call through using some of its morphological characteristics. Accordingly, the agricultural experts do not know the surplus, available and deficient nutrients in the soil to supply the required amount of fertilizers to the cultivated crop and it is also difficult to recommend other management strategies. This situation creates conducive environment for the expansion of unwise land use practices and assigning lands without considering its capability and suitability classes for any crop grown in the district. For that, the soil may be exposed to degradation and depletion of fertility potential. Hence, the farmers in the study area favors the use of extensive system of farmland expansion in terms of destroying the available shrub and grass land with its ecosystem to maximize their crop yields rather than searching a solution for the degraded land. Therefore, the significance of the study was to characterize and classify soils of Jello Chancho Watershed to generate standard information, which is important for formulating the management alternatives for different soil types. The specific objectives of the study are to characterize the physical and chemical properties of the soil, and also to classify the soils in the study area according to World Reference Base Legend.

MATERIALS AND METHODS

Description of the study area

The study was conducted on Jello Chancho Watershed, Liban district of East Shewa zone, Oromia region, Ethiopia. It is located on the 61 km in south east direction from Addis Ababa. Geographically, it is located between 8° 27' 30" - 8° 37' 00" N latitude and 38° 57' 00"-39° 70’ 00" E longitude with altitudinal range of 1600-2001 m above sea level (Figure 1) (LWAO, 2010). The lowest and highest annual average temperatures are 18 and 30°C, respectively. The rainfall of the area is bimodal, with short rains from March to April and the main season ranging over June to September. The area is receiving rainfall ranging from 430-1600 mm with bimodal pattern; namely summer (*Rooba Gannaa)* from mid-June to September and spring (*Rooba Arfaasaa*) from March to June. Agro-ecologically, the study area is characterized by Wayne Dega (*Badda Daree*) (LWAO, 2010).

The study area is characterized by flat (0-0.2%), gentle slope (0.2-5%), moderate slope (5-10%) and strongly slope (10-15%); which means moderate slope at the tip of the study area which covered small area of upper part and most area is very gentle and level slope. There are some seasonal rivers and permanent springs in the study area (LWAO, 2010).

Mixed farming system that comprises crop and livestock production is practiced in the Jello Chancho Watershed. Crop production is practiced under rain-fed and irrigated conditions and is the main agricultural activity in the area. Both non-flooded and flooded areas are used for crop production. In non-flooded areas, Teff, wheat, barley, maize and sorghum are produced. Important grains legumes are pea, beans, rough peas and lentils along with oil crops like groundnut, sesame and rape seed. However, in flooded areas, vegetables are the most predominantly grown crop although its area coverage is very small. The main water resources for irrigation agriculture are river water and hand-dug wells (LWAO, 2010).

The study watershed contained both indigenous and exotic plant species. There are several diversities of native plant species such as *Waddeessa* (*Cordia africana*), *Ejersa (Olean africana), Laaftoo*

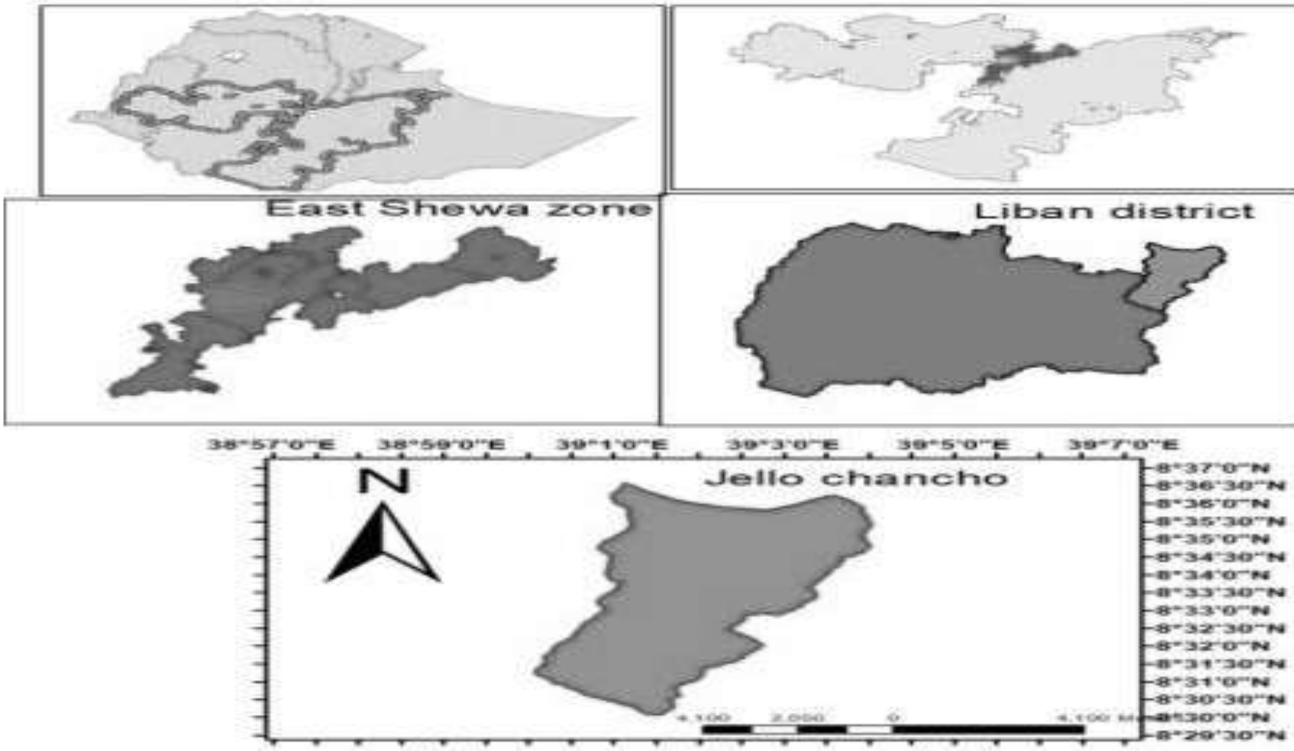

Figure 1. Location of the study area. *, ** = Significant at P = 0.05 and P = 0.01; Par= parameters, CEC = Cation exchange capacity; EC = Electric conductivity; PBS = Percent base saturation; TN = Total nitrogen; OM = Organic Matter; BD = Bulk density, Av.P= available phosphorous, P% =Porosity percentage, Ca = Calcium, K= Potassium.

(Acacia tortilis), Garbii (Acacia nilotica), and *Waaccuu (Acacia seyal*) that are visible sparsely over the study area with some shrubs covering the upper part the study area. Additionally, there are some exotic species such as *Giraafillaa (Gravillia), Gaattiraa* (*Juniperus procera)* and *Baargamoo* (*Eucalyptus)* species. Eucalyptus tree has been planted around homesteads, in between farm boundaries, and as a woodlot by farmers for generation of fuel wood, timber, cash income, and construction material source.

Site selection

Before the excavation of soil profiles, a general visual reconnaissance survey was carried out within the study area to identify the major soils in the watershed. Free soil survey methods were employed to select profile excavation points as a major survey method along landform to identify variability of soils in the study area. Depending on physical observations, a total of 54 auger samples were taken from all parts of the study area and some morphological properties of the soil color, consistency and structure were analyzed in the field in order to observe the extent of variation of soil attributes. Field observation and auger samples at depth of 0-15 cm were used to identify some morphological properties of surface soil such as depth, structure, color and consistency to determine how many profiles would represent the watershed. Additionally, simple visual observation was used to identify the slope (upper slope, middle slope and lower slope) and land use (shrub, cultivated and grassland) to identify the representative number of profile for study area. Depending on the visual observation of landform features, auger samples and land use, three representative sites were selected and one profile was excavated in each site with 2 m length by 2 m width and 2.0 m depth.

Soil profile sampling

The newly opened representative soil profiles were illustrated and the horizons described *on site* according to guidelines of FAO for soil description (FAO, 2006). All necessary physical and morphological properties along with other important site information were recorded on a standard soil site and soil profile description sheets right at the field. Soil samples were collected from each horizon for characterization of their physical, chemical properties and for soil classification.

Soil sample preparation and laboratory analysis

Collected soil samples were carefully bagged, sealed, labeled in plastic and the packed samples were transported to the Oromia Water Works Design and Supervision Enterprise Soil Laboratory at Addis Ababa for preparation and analysis. The samples were air-dried at room temperature, ground using mortar and pestle and made to pass through 2-mm sieve in the laboratory for all the soil parameters except for soil total N and organic carbon (OC). For analysis of OC and total N, the soil samples were further passed through 0.5-mm sieve. Finally, the soil samples were analyzed for selected physical and chemical properties following the standard analytical procedures.

Analyzed soil physical properties include soil texture (particle size distribution) and bulk density. The procedure described by the FAO

(2014) was used to determine the soil texture (particle size distribution) following the hydrometer method (Sahlemedhin and Taye, 2000) and from that result the soil textural classes were determined while bulk density was determined from undisturbed soil samples following the core sampling method (BSI, 1975). Finally, soil total porosity (TP) was calculated from the values of bulk density (BD) and the average particle density (PD) of mineral soil (2.65 g/cm$^{3)}$ BSI (1975) as:

$$Total\ Porosity\ (TP\ (\%) = \left[1 - \left(\frac{bd}{pd}\right)\right] * 100 \quad (1)$$

Where bd is bulk density (g cm^{-3}), and pd is particle density (g cm^{-3}).

The soil chemical properties that were studied include soil pH, soil organic carbon, total nitrogen, percentage base saturation (PBS), available phosphorous, exchangeable bases (Ca, Mg, K and Na), electrical conductivity (EC) and cation exchange capacity (CEC).

The pH of the soil was determined in water (H_2O) using a 1:2.5 soil to water ratio (Van Reeuwijk, 1993) whereas EC was measured by conductivity meter on saturated soil paste extracts obtained by applying suction (Okalebo et al., 2002). The organic carbon of the soils was determined following the wet digestion method as described by Walkley and Black (1934) while the organic matter (OM) was computed from organic carbon (OC). The total nitrogen of sampled soil was determined by the Kjeldahl digestion, distillation and titration method (Bremner and Mulvaney, 1982) and Av.P was determined using the standard Olsen extraction method (Olsen et al., 1954) whereas CEC was determined at pH by1N ammonium acetate method in which it was, subsequently, estimated titrimetrically by distillation of ammonium that was displaced by sodium (Chapman, 1965). The exchangeable bases (Ca, Mg, K and Na) in the soil were determined from the leachate of 1 molar ammonium acetate (NH_4OAc) solution at pH 7. Exchangeable Ca and Mg were measured by AAS, while K and Na were read using flame photometer (Rowell, 1994) and PBS was computed from sum of exchangeable base to CEC of the soil.

Statistical analysis

Simple correlation analysis was carried out with the help of Statistical Package for Social Science (SPSS) version 20.0 model to reveal the magnitude and directions of relationships between selected soil physicochemical properties (SPSS, 2001).

Soil classification

Considering the site characteristics, field analysis and profile description, a preliminary soil classification was made in the field. Depending on physical, morphological and chemical properties, the soils of the current study area were finally classified into different units (major soil) according to the FAO (2014) legend.

RESULTS AND DISCUSSION

Morphological and physical properties of soil

Soil depth, color, structure, consistence, texture, density (bulk and particle) and porosity are some morphological and physical properties of the soil while altitude, topography, land use type and soil management history were considered as the physiographic features of the study area (Table 1)

Soil depth

Total depth of profiles were 81, 107 and 200 cm for the upper, middle and lower slope, respectively with the identified horizon having variable thickness. The upper slope had a surface horizon and thickness of 26 cm. The identified subsurface horizon next to surface horizon was B horizon. Its thickness was 21 cm whereas the below horizon was C horizon and its thickness greater than overlying horizon. The total depth of identified horizon profile 1 (upper slope) was 81 cm. In general, the depth of each horizon were 0-26, 26-47 and >47 cm representing A, B and C horizon, respectively. Generally, the depth of profile 1 was shallow while compared with other profiles that were opened in the middle and lower part of the study area (Table 2).

The total depth of profile 2 was deep (>100 cm). But it was shallow than the depth of profile 3 and deeper than profile 1. The depth of upper part profile was less than the depth of middle and lower part profiles because of the movement of soil and soil materials from the upper part to lower part through gravity and erosion. In line with this result, Mohammed et al. (2017) reported that the slope incline could be the major factor in affecting the depth of the soil which means there is the deposition of the soil from upper part of the watershed to lower part of the watershed due to slope gradient. The recognized genetic horizon had different thickness in profile 2 (middle slope), which means surface horizons (A*p*) had around 21 cm thickness. Below Ap horizon about 12 cm thick subsoil horizon (AB) was recognized. Below AB horizon around 26 cm thick another subsoil horizon (Bt1) was recognized and the forth horizon which had 49 cm thick subsoil horizon (Bt2) was recognized (Table 2).

The third (profile 3) was opened in grassland at the lower slope of the study area (Table 2).. The total excavated depth of profile 3 was 200 cm, which means very deep than other profiles that opened in the upper and middle part of the study area due to no severe soil erosion at lower part and sedimentation of soil from upper parts to lower. The continuous addition and accumulation of grass and grass root with no severe erosion could also play great role for the thickness depth of profile 3 that was opened in the grassland of lower part. The identified horizon had variable thickness with irregular change from surface to subsurface. The thickness of identified horizons was 24, 19, 94 and 63 cm in which assigned A, AB, Bt1 and Bt2, respectively. In general, the depth of the soil increased down topographic position indicating the dominance of soil movement (erosion) over the accumulation on the upper position and otherwise in the lower topographic position (Nahusenay et al., 2014).

Soil color

Surface horizon of profile 1 had dark reddish brown (5YR3/3) color in dry soil and changed to dark reddish

Table 1. Selected site characteristics of representative soil profiles.

Profile	Location		Altitude (m)	Slope (%)	Slope position	Drainage class	Erosion / deposition	Parent material	Land use
	Latitude	Longitude							
1	8°35'17''N	39o2'25''E	1969	12	Upper slope	Well drainage	Erosion /rill erosion	Colluvial	Shrubs land
2	8°33'48''N	39o2'37''E	1714	2	Middle slope	Well drainage	slight sheet erosion	Alluvial	Cultivated land
3	8°31'42''N	39o0'45''E	1678	0.1	Lower slope	Weakly drainage	Deposition	Alluvial	Grass land

Table 2. Morphological properties of soils of the study area.

Horizon	*Depth (cm)*	*Color*		*Structure grade /size/ type/*	*Consistence*			
		Dry	**Moist**		**Dry**	**Moist**	**Stick**	**Plastic**
Profile 1 (Upper slope*)*								
A	0-26	2.5YR4/3	5YR3/3	MO,ME,GR	SHA	FR	SST	PL
B	26-47	10YR4/3	2.5YR3/4	MS,ME,PR	HA	FI	ST	PL
C	47-81+	7.5YR8/2	7.5YR8/2	ST,VC, B	VHA	FR	NST	NPL
Profile 2 (Middle slope*)*								
Ap	0-21	10YR4/2	10YR3/1	WE,F,GR	SO	FR	SST	SPL
AB	21-33	10YR5/2	7.5YR3/1	MO,ME,GR	SHA	FI	SST	PL
Bt1	33-59	10YR3/1	7.54/1	ST, VC,PS	HA	VFI	VST	VPL
Bt2	59-107	10YR5/6	5YR3/2	MO,C,SB,	HA	FI	ST	PL
Profile 3 (Lower slope)								
A	0-24	10YR4/1	10YR2/1	ST,VC,GR	SHA	FR	ST	VPL
AB	24-43	7.5YR6/1	10YR4/2	WE,F, PR	SHA	FI	SST	PL
Bt1	43-137	7.5YR3/1	7.5YR2.5/2	MO,ME,PR	VHA	VFI	VST	VPL
Bt2	137-200+	10YR5/6	10YR4/4	MO,ME,PS	HA	FI	ST	PL

According to FAO (2014), MO=moderate, ME=medium, WE=weak, SB=sub angular blocky, F= Fine, GR= granular, AB=angular blocky, B=Blocky, PR= prismatic, ST= strong, C=coarse, VC=Very coarse, MS=medium to strong, PS= subangular prismatic,SO=soft, SHA=Slight hard, HA=Hard, VHA= very hard, HVH= hard to very hard, FI= firm, VFI= very firm, FR= friable, ST= sticky, SST = slight sticky, PL=plasticity, NST= non sticky, NPL= non plastic, SPL= slightly plastic VPL=very plastic.

brown (2.5 YR3/3) in moist soil, brown (10YR4/3) in dry soil to dark reddish brown (2.5 YR3/4) in moist soil of B horizon and pinkish white (7.5YR8/2) in dry soil to no change in moist soil in C horizon. In profile 2, the surface horizon (Ap horizon) had dark gray brown (10YR4/2) in dry soil and very dark grayish brown (10YR3/1) moist soil, grayish brown (10YR5/2) in dry soil and very dark gray (7.5YR3/1) in moist soil of AB horizon, very dark gray (10YR3/2) in dry soil and dark gray (7.5YR4/1) in moist soil of Bt_1 horizon whereas yellowish brown (10YR5/6) in dry soil and dark reddish brown (5YR3/2) in moist soil of bottom subsurface (Bt_2 horizon) soil. The surface A horizon of profile 3 had dark gray color (10YR4/1) in dry soil and black (10YR2/1) in moist soil, gray (7.5YR6/1) in dry and dark greyish brown (10YR4/2) in moist soil of AB horizon, very dark gray (7.5YR3/1) in dry and very dark gray (7.5YR2.5/2) in moist soil of Bt1 horizon and it showed yellowish brown (10YR5/6) in dry with dark yellowish brown (10YR4/4) in moist soil of lower subsurface Bt2 horizon of the soil. The color of the soils were dark reddish brown, brown and pinkish white in dry soil of horizons A, B and C profile 1 respectively. The color of profile 2 was Dark gray brown, Grayish brown, very dark gray and Yellowish brown in which there was dry soil of Ap, AB, Bt_1 and Bt_2 horizon respectively, whereas the soil color of profile 3 was dark gray, Gray, very dark gray and yellowish brown in which there was dry soil of A, AB, Bt_1 and Bt_2 horizon, respectively.

Generally, the soil color of the study area was black, dark gray brown, and dark reddish brown in which there was surface horizon of profile 3, 2 and 1 respectively. The change from dark reddish brown color in surface soil to pinkish white color in subsurface soil horizons in profile 1, dark gray brown to reddish brown in profile 2 and black to dark yellowish brown in profile 3 show the existence of high OM values in surface horizons than in subsurface horizon. That means black or dark color of the soil show the presence of high organic matter while reddish color shows the presence of other mineral such as Fe in subsurface horizon and drainage pattern also play great role for the variation of color between different profile and topography. This means topography influences the amount of surface runoff, erosion and deposition. If erosion removes soil from upper slope or middle areas of the hill slope, light colored and thinner remain where the organic matter content is low. Moreover, soils on slope that were never saturated with water had reddish and brown subsoil colors which are reveals well drained and aerated conditions. Reddish color is because of the existence of iron compounds in various states of hydration and oxidation (Chimdessa, 2016).

Soil structure

The structure of surface horizon of profile 1 was moderate medium granular that changed to medium to strong; medium prismatic structure in B horizon and the bottom subsurface horizon had strong very course angular blocky structure. The surface horizon of profile 2 had weak fine granular arrangement, and it changed to moderate medium granular structure in underlying horizon (AB horizon) and to strong very coarse sub-angular prismatic in upper subsurface horizon (Bt1), while the bottom subsurface horizon of profile 2 (Bt2 horizon) had moderate coarse sub-angular blocky structure. Finally, the surface horizon of profile 3 had strong very coarse granular structure. Because of different grass root found in the surface part of the profile, it had granular arrangement and changed to weak fine prismatic structure in AB horizon. Both Bt1 and Bt2 had moderate medium prismatic and moderate medium sub-angular prismatic structure, respectively. The same results reported by Kebede et al. (2017) who found granular soil structure in the surface horizons changed to angular and sub-angular structure in the subsurface profiles. The existence of organic matter in the surface soil might be attributed to the formation granular type of the soil. In general, the variations in the structure among horizon suggest the presence of vertical variability in development of soil profile (Mohammed et al*.,* 2017).

Soil consistency

The surface horizon of profile 1 had slightly hard (dry), friable (moist) and slightly stick and plastic (wet) consistency. The sub-surface B horizon had hard (dry), firm (moist) and stick and plastic (wet) consistency whereas horizon underlying (C horizon) had very hard (dry), friable (moist) and non-stick and non-plastic (wet) consistency. The surface soil horizon of profile 2 had soft (dry), friable (moist) and slightly stick and slightly plastic (wet) consistency. The subsurface AB horizon had slightly hard (dry), firm (moist) and slightly stick and plastic (wet) consistency and it changed to hard (dry), very firm (moist) and very stick and very plastic (wet) consistency on B_{t1} horizon while B_{t2} horizon had hard (dry), firm (moist) and stick and plastic wet) consistency. Finally, the surface horizon of profile 3 had slightly hard (dry), friable (moist) and sticky and very plastic (wet) consistency. It changed to slightly hard (dry), firm (moist) and slightly sticky and plastic (wet) consistency in AB horizon. The subsurface B_{t1} horizon had very hard (dry), very firm (moist) and very stick and very plastic (wet) consistency while subsurface B_{t2} horizon had hard (dry), firm (moist) and stick and plastic (wet) consistency.

Generally, there were changes in consistency with topographic position; land uses system and depth in most soil horizons of profiles in study area. The surface soil of middle slope had soft consistency and changed to slightly hard in lower slope position. This result is in agreement with Kebede (2006), which reported that, the dry soil consistency was different along the topographic position. Accordingly, upper slope area had soft to slightly hard, whereas the lower slope soil had slightly hard to very hard consistency and the change related to consistency characteristics might be related to change in soil texture. As indicated by Abay et al*.* (2015), the sticky, very sticky, plastic and very plastic consistencies show the presence of high clay content, and difficulty to tillage. Wendemeneh (2010) also indicated that the change in consistency characteristics from surface to subsurface reflects low amount of organic matter of subsurface horizon; which means the friable consistence observed in the surface soils of the profile could be attributed to the higher OM content. Therefore, the surface soil of the study watershed had friable consistence in moist condition in all land use and topographic position due to higher values organic matter in surface than subsurface horizon.

Particle size

The textural classes of profile 1 was loam, clay loam and loam in which there was horizon A, B and C, respectively, whereas the textural classes of profile 2 was loam, loam, clay loam and loam in which there was horizon Ap, AB, Bt1 and Bt2, respectively and for profile 3 was clay loam, loam, clay and loam in which there was horizon A, AB, Bt1 and Bt2, respectively (Table 3).

The textural class of surface and underlying subsurface horizon (AB) of profile 2 was loam. It changed to clay in the upper subsurface (B_{t1}) horizon and to loam in the bottom subsurface horizon (B_{t2}). In agreement with this result, Kebede (2006) found the accumulation of clay in subsurface horizons and attributed this to be on site formation of secondary clay, weathering of primary minerals in B horizon or the residual concentration of clay from selective dissolution of more soluble minerals. Finally, the textural class of surface horizon (A) and its underlying horizon (AB) of profile 3 were clay loam and

Table 3. Selected physical characteristics of soil profiles.

Depth (cm)	Horizon	Particle size analyses (%)			Textural class	Si/c	BD. (g/cm3)	Porosity (%)
		Sand	Silt	Clay				
Profile 1 (Upper slope)								
0-26	A	39	45	16	Loam	2.80	1.00	62.27
26-47	B	33	35	32	Clay loam	1.09	0.91	65.66
47-81+	C	45	29	26	Loam	1.11	1.06	60.00
Profile 2 (Middle slope)								
0-21	Ap	41	43	16	Loam	2.68	0.90	66.00
21-33	AB	47	35	18	Loam	1.95	0.97	63.40
33-59	Bt1	29	29	42	Clay	0.70	1.07	59.62
59-107	Bt2	43	35	22	Loam	1.60	1.09	58.87
Profile 3 (Lower slope)								
0-24	A	25	41	34	Clay loam	1.20	0.91	65.66
24-43	AB	37	41	22	Loam	1.86	1.11	58.11
43-137	Bt1	27	29	44	Clay	0.66	1.02	61.05
147-200+	Bt2	37	37	26	Loam	1.03	1.18	55.47

Si=Silt, C= Clay, BD= Bulk density.

loam respectively and it changed to clay as the percentage of clay increase and increase in subsurface of B_{t1} horizon.

The textural classes of the surface horizon of profiles varied from loam in profiles 1 and 2 to clay loam in profile 3. This indicates that the fines textured particles increase down the slope in the Jello Chancho Watershed. On the other hand, the subsurface horizon textural classes ranged from loam to clay. In addition to variation in textural classes among the profiles, within profiles and with depth were also observed, except in the bottom layer of the profiles. There were unsystematical rising in clay contents with the depth in most profiles. This may be because of the susceptibility fine particles to loss and leaking. Accordingly, the general increase in clay content with depth might be attributed to the vertical translocation of clay through the processes of illuviation. Higher clay content in the B horizon of soils as a result of illuviation, predominant *in situ* pedogenetic formation of clay in the subsoil, and obliteration of clay in top horizon, has been reported (Kebede et al*.,* 2017).

Soil bulk density

The bulk density of the soil in the study area ranged from 0.91-1.06, 0.90-1.09 and 0.91-1.18 grcm^{-3} for profile 1, 2 and 3, respectively (Table 3). There was a little variation in bulk density with depth and topographic position of the study area. The bulk density values of the top horizons varied from 0.9 to 1.0 grcm^{-3} recorded in profiles 1 and 2 respectively, whereas the bulk density values of subsurface horizons varied from 0.91 to 1.18 grcm^{-3} was recorded in B horizon profile 1 and B_{t2} horizon of profile 3 respectively. Generally, Bulk density varied inconsistently with depth of soil in all profiles and topographic position in the study area. But in total average, the bulk density of surface horizon is less than the bulk density values of the subsurface horizons.

The relatively lower bulk density values (≤1 gcm^{-3}) in the top horizon of all profiles could be related to structural aggregation of the soils as a result of relatively higher values of organic matter content.

The bulk density in soils, irrespective of landforms, increased with depth which might be due to weight of the overlying soil and the relatively low amount of organic matter in the subsurface soil layers. Similarly, Kassa and Kibret (2013) reported increase in bulk density with profiles depth, due to low values of organic matter content, low porosity, and high compaction in subsurface soil than surface soil.

Additionally, some authors reported that the low bulk density value at surface horizon could be because of the more organic matter which resulted in high total porosity. On the other hand, high bulk density values in lower horizon could be due to compaction caused by the weight of overlying soil material and reduced root penetration (Brady and Weil, 2008). On the other hand, the bulk density values of the soils in the Jello Chancho Watershed were not too compact to limit root penetration and restrict movement of water and air. This denotes the presence of friable soil condition in the surface horizons of the profiles which is in agreement with Bohn et al*.* (2001).

Table 4. Selected chemical characteristics of soils of the Jello Chancho Watershed.

Depth (cm)	Horizon	PH (H_2O)	EC (ds/m)	OC (%)	TN (%)	Av. P (mg/kg)	C/N	OM (%)
Profile 1 (Upper slope)								
0-26	A	5.6	0.106	2.59	0.23	2.98	11:1	4.47
26-47	B	5.7	0.097	0.86	0.07	1.44	12:1	1.49
47-81+	C	5.7	0.070	0.32	0.03	0.02	11:1	0.56
Profile 2 (Middle slope)								
0-21	Ap	5.6	0.112	1.12	0.10	2.94	11:1	1.93
21-33	AB	6.2	0.095	0.74	0.08	1.08	9:1	1.27
33-59	Bt1	6.4	0.175	0.52	0.05	1.72	10:1	0.89
59-107	Bt2	7.0	0.443	0.48	0.04	0.68	12:1	0.83
Profile 3 (Lower slope)								
0-24	A	6.1	0.126	1.78	0.17	3.86	10:1	3.07
24-43	AB	6.2	0.083	0.57	0.05	0.06	11:1	0.98
43-137	Bt1	6.5	0.245	0.55	0.06	0.22	9:1	0.95
137-200+	Bt2	6.7	0.241	0.22	0.02	0.02	11:1	0.37

Soil porosity

The soil porosity of the study area was ranged from 60-65.66, 58.87-66 and 55.47-65.66 under profiles 1, 2 and 3, respectively (Table 3). Following the variation in bulk density and average particle density of mineral soil, the total porosity of the soil under study area revealed difference within depth of profiles, land uses and topographic position. Consequently, the total porosity of the studied soil ranged from 55.47 to 66.00% in different slope position. The lowest (55.47%) and highest (66.00%) total porosity were recorded in subsurface Bt2 horizon of profile 3 and surface horizon of profile 2 (middle land) respectively. In general, porosity did not show any consistent variation within profile, with soil depth and down topographic position. However, in majority of the cases the surface horizon had relatively higher total porosity than the underlying subsurface horizon. This might be due to higher bulk density in subsurface horizon than surface horizon and higher organic matter in the surface horizons. In line with this, Negassa (2001) reported that the lower total porosity in the subsurface layer is a result of low OM contents and high bulk density. According to Brady and Weil (2008), the ideal porosity value for healthy root growth is > 50%. Thus, porosity values of the recognized profiles in the surface and subsurface layers are in the acceptable range for crop production. Therefore, the total porosity observed on both subsurface and surface horizons could allow the soils of the study area to deliver good aeration for crop production and different soil microorganisms.

Soil chemical properties

Electrical conductivity (EC) and pH of the soil

Soils pH in the current study area ranged from 5.6-5.7, 5.6-7.0 and 6.1-6.7 for profiles 1, 2 and 3, respectively (Table 4). The pH of profile 1 was ranged from 5.6-5.7 which was rated as moderately acid, the pH of profile 2 was ranged from 5.6-7.0 which was rated as moderately acidic, slightly acidic and neutral while the pH of profile 3 was ranged from 6.1-6.7 which was rated as slightly acidic and neutral. The pH values of all profiles showed rising tendency with depth ranged from 5.6-5.7, 5.6-7.0 and 6.1-6.7 of surface to bottom subsurface horizons profiles 1, 2 and 3 respectively. Enlarged pH of all the profiles with depth of the soil may denote the existence of vertical movement of most exchangeable bases and less H^+ ions are released from decay of OM. Inverse relation is between organic matter and pH of the soil in Jello Chancho Watershed, and this is in line with the result of Abay and Sheleme (2012), which reported that the increased pH values with soil depth might be due to less H^+ ions released from low organic matter decay, which is caused by reduced organic matter content with depth. Additionally, Shimeles et al. (2006) suggest that the lower pH values at the surface soil might be due to the seasonal soil saturation that may have resulted to base removal from horizon and contribute to reducing the soil pH value.

The soil EC of Jello Chancho Watershed was ranged from 0.070-0.106, 0.095-0.443 and 0.083-0.245 dSm^{-1} in which profile 1, profile 2 and profile 3 respectively (Table 4). There was no consistent relationship between measured electrical conductivity values and depth in soil profiles for studied area. The values of EC studied soil in upper slope were 0.106, 0.097 and 0.07 dSm^{-1} in horizons A, B and C respectively and also the values of EC in studied soil profile 2 was 0.112, 0.095, 0.175 and 0.443 dSm^{-1} for horizons Ap, AB, Bt1 and Bt2 respectively whereas the values of EC in profile 3 were 0.126, 0.083, 0.245 and 0.241 dSm^{-1} in horizons A, AB, Bt1 and Bt2 respectively. The subsurface horizon of profile 2 (Bt2 horizon) had high reading of EC than other horizons of profiles under study area.

In short, due to moderate acid to neutral nature of most soil of the study area, the electrical conductivity value was less than 1 dSm^{-1}. The relatively high values of EC of extract soil were recorded in subsurface horizon of pedon 2 which was 0.443 dSm^{-1}. The EC values in all profiles were rated as salt free according to Shaw (1999) who rate EC<2 as salt free, 2-4 as very slightly saline, 4-8 as slightly saline, 8-16 as moderately saline and >16 strongly saline due to EC values of the study area were ranged from 0.070-0.443 dSm^{-1}. In general, the measured electrical conductivity values through the depth in the current watershed denote that the concentrations of soluble salts were less than the levels at which productivity and growths of most crops are affected due to salinity.

Soil organic matter (SOM)

The SOM contents of study area were ranged from 0.56-4.47, 0.83-1.93 and 0.37-3.07% for upper, middle and lower slope respectively (Table 4). Organic matter contents of the soil in all profiles were in the range between 0.37 and 4.47%. Accordingly, the OM content of surface soil in the Jello Chancho Watershed was low in middle slope and high in lower and upper slope. The content of organic matter varied from 0.56 to 4.47%, 0.83 to 1.93% and 0.37 to 3.07% were generally lower subsurface to surface of profiles 1, 2 and 3 respectively. The organic matter content of profile middle slope was varied from 0.83 to 1.93% which ranged between very low and low. While the organic matter content of profile 3 was varied from 0.37-3.07% and ranged between very low and high rates. However, the organic matter contents of surface horizon of all profile were very high than the subsurface horizon of the profiles. Higher contents of OM in the surface horizons of profiles 1 and 3 could be used for describing the existence of enough shrub leaf, grass roots and other parts grass for disintegration. In line with this study, Wendemeneh (2010) and Sheleme (2011) reported that surface horizon showed higher OM content than subsurface horizons which could be because of its frequent addition and accumulation of litter and annual grasses. Organic matter contents of cultivated land was also lower because in most cultivated lands, the decomposition of root is the major source of organic matter accumulation since above ground parts are removed to be used as feed for livestock (Haile, 1987).

Total nitrogen (TN) and Carbon to Nitrogen ratio (C:N)

The TN of the soil in the study area was 0.03-0.23, 0.04-0.10 and 0.02-0.17 for profiles 1, 2 and 3 respectively (Table 4). The amount of total nitrogen also showed variation within and among profile in relation to level of organic matter. It shows the same trend as soil OM. Total nitrogen was high in surface horizon and showed systematic decrease with profiles 1 and 3. The surface total nitrogen contents were low in the middle slope (cultivated land) than shrubs land and grass land (lower slope). It might be because different crops residues are continuously removed from the field as they are used as source of fuel, livestock feed and income generation. Farmers cut their crops during harvesting close to the surface and as a result no more residues are found in the field. Even after harvesting, animals are allowed to pick up what is left in the field. The continuously declining soil N leads to the soil to be less fertile and fail to sustain agricultural production. The year-after-year application of N containing chemical fertilizer, which in general was insufficient to replace off-take, shows the N content in soil is declining. In line with this finding, Gebreselassie (2002) reported the lowering of total nitrogen in cultivated land due to complete removal of biomass from the field for feed livestock and other income generation.

Carbon to nitrogen ration of the soil in the study area ranged from 11:1-12:1, 9:1-12:1 and 9:1-11:1 under profiles 1, 2 and 3, respectively (Table 4). The C/N ratio of surface horizon of the study area ranged from 10:1 in profile 3 to 11:1 in profiles 1 and 2. It showed inconsistent relationship with depth in all profiles of studied area. The high values of C/N ratio (12:1) observed in the upper subsurface (B horizon) of profile 1 and lower subsurface (Bt2 horizon) of profile 2 which has low temperature at highest elevation (upper and middle) than lower part of the study area. The surface carbon to nitrogen ration of upper slope was greater than the C/N ratio of lower slope. This difference might be qualified by the presence of OM with relatively high lignin and other hard substances that are resistant to decomposition in the upper slope position and short term saturation of soil in the upper slope position. In short, carbon to nitrogen ratio is an indicator of nutrient immobilization and mineralization whereby low C/N ratio indicates higher rate of mineralization and higher C/N ratio indicates greater rate of immobilization (Anbessa, 2018). In general, a C/N ratio about 10:1 suggest relatively better decomposition rate serving as index of improved N availability to plant and to possibilities to incorporate crop residue to the soil without having any adverse effect on N immobilization (Assen and Yilma, 2010). Accordingly, the C:N ratio of the surface soils across the sites was not far apart from optimum range in all soils for microbial needs.

Available phosphorous

Available phosphorous (Av. P) of the soil in Jello Chancho Watershed were ranged from 0.02-2.98, 0.68-2.94 and 0.02-3.86 mg/kg for which there were profiles of upper, middle and lower slope respectively (Table 4). Variation in available phosphorous with soil depth and

Table 5. Exchangeable cations, cations exchange capacity, percent base saturation and total exchangeable base of soils of the study area.

Depth (cm)	Horizon	Exchangeable cations				Sum ($Cmol_ckg^{-1}$)	CEC ($Cmol_ckg^{-1}$)	PBS (%)
		Ca	Mg	Na	K			
Profile 1 (Upper slope)								
0-26	A	29.53	5.25	0.08	1.15	36.00	68.2	53
26-47	B	27.72	7.37	0.2	1.39	36.68	46.6	79
47+	C	12.27	3.48	0.10	0.70	16.55	18.9	88
Profile 2 (Middle slope)								
0-21	Ap	17.25	3.98	0.26	1.38	22.88	23.4	98
21-33	AB	15.92	4.34	0.89	1.31	22.46	26.3	85
33-59	Bt1	36.08	6.65	1.22	6.32	50.28	57.0	88
59-107	Bt2	30.34	5.60	1.39	7.04	44.38	45.5	98
Profile 3 (Lower slope)								
0-24	A	28.56	7.22	0.28	3.88	39.93	45.5	88
24-43	AB	17.23	3.66	0.74	1.21	22.84	27.5	83
43-137	Bt1	33.74	5.28	1.19	3.27	43.47	56.0	78
137-200+	Bt2	37.13	6.23	1.23	4.06	48.65	51.1	95

along topographic position were also recorded. Generally, Av. P showed rising trend down the topographic position and unsystematically reduced with depth of profiles. The surface soil of the study area had higher reading of available Phosphorous than subsurface soil of the study area. This might be because of better content of OM at the surface layers. This is in agreement with the finding of Tedesse (1991) who reported that the available phosphorous of the surface soil is usually greater than that of subsurface soil due to high microbial activity and building up of organic material on the surface soil.

As rates of available phosphorous set by Jones (2003), the available phosphorous of the Jello Chancho Watershed is very low (1-5 ppm). This might be due to the susceptibility of soil of study area to erosion and lack of soil management practice. The available phosphorus of Ethiopian soil is low due to severe soil erosion, intensive crop harvest, low rate of phosphorous source application and inherently low phosphorous content and high P fixation capacity (Kebede et al., 2017).

Cation Exchange Capacity (CEC)

The CEC of the soil in the study area ranged from 18.90-68.20, 23.40-57.0 and 27.50-56.0 $cmolckg^{-1}$ for upper, middle and lower slope, respectively (Table 5). Its contents in both top and bottom horizons ranged from 18.90 $cmolckg^{-1}$ (profile 1) to 68.20 $cmolckg^{-1}$ at the same profile opened at upper slope (shrubs land) and in general it rated between medium and very high according to Landon (1991). The lessen values of cation exchange capacity (18.2 $cmolckg^{-1}$) was recorded for bottom subsurface horizon of profile 1, where most exchangeable bases were found to be low than in other horizons. Generally, there was decrease in cation exchange capacity with depth in profile 1 which could be due to strong association between OC and cation exchange capacity. This finding is in agreement with Kedir (2015) who reported that the variation in CEC is due to variation in OM which means increase in OM caused the increment of CEC. In the case of land use, the CEC values of the study area was higher in shrubs land (upper slope) and grassland (lower slope) than the value of CEC in cultivated land in middle slope. This might be because of higher values of OM content in shrubs and grassland than cultivated land. This is in line with Bore and Bedadi (2015) who stated the soil cation exchange capacity values in agricultural land uses reduced because of the reduction in organic matter content.

Percentage of base saturation (PBS)

The percentage of base saturation in the study area were ranged from 53-88, 85-98 and 78-95% for profile 1 (upper slope), profile 2 (middle slope) and profile 3 (lower slope), respectively (Table 5). The percent base saturation increased with depth in profile 1 while it was inconsistent in the other profiles and topographic positions. Percent base saturation of surface soil horizons ranged from 53% in profile 1 (upper slope) to 98% in profile 2 (middle slope). In the subsurface soils, PBS ranged from 78% in the Bt1 horizon of profile 3 (lower slope) to 98% in the Bt2 horizon of profile 2 (middle slope). The PBS values in the study area ranged from medium (40-60%) in surface horizons profile 1 to very high (>80%) in most horizons based on the rating of Metson (1961). Additionally, percentage of base saturations levels denote the intensity of leaching or coverage of leaching in the sense of depilation of the exchangeable bases. Accordingly, the percentage of base saturation of the soil of the study area could be categorized as weakly leached (50-70%) and very weakly leached (70-100%). Percentages of base saturation values of soil in most part of study area categorizes under fertile soil because its PBS values were high and very high. Landon (1991) also stated the soil which has PBS> 60% was categorized under fertile soil.

Exchangeable bases

Exchangeable Ca of the soil in the study area was ranged from 12.77-29.53, 15.92-36.08 and 17.23-37.13 cmolckg^{-1} in profiles 1, 2 and 3 respectively (Table 5). Concentration of Ca decreased consistently with depth in profile 1 and increased inconsistently with depth of the soil profiles 2 and 3. The highest value (37.13 cmolckg^{-1}) was recorded in the bottom layer of profile 3 and the lowest (12.27 cmolckg^{-1}) was recorded in bottom horizon profile 1. Considering the effects of topographic position, the content of Ca^{2+} decreased unsystematically from the upper slope to the lower slope. Accumulation of Ca^{2+} with depth could be attributed to the leaching by high amount of rainfall in the area. Supporting this finding, Nahusenay et al. (2014) indicated that accumulation of exchangeable Ca^{2+} with depth could be due to leaching from the overlying horizons. According to the rating set by FAO (2006), the concentration of exchangeable Ca observed in all surface horizons are categorized as high to very high levels.

The exchangeable Mg of the soil in the study area was ranged from 3.48-5.37, 3.98-6.65 and 3.66-7.22 cmolckg^{-1} in profiles 1, 2 and 3 respectively (Table 5). Exchangeable Mg contents varied from 3.98 cmolckg^{-1} in profile 2 to 7.22 cmolckg^{-1} in profile 3 of the surface horizons and 3.48 cmolckg^{-1} in C horizon of profile 1 to 7.37 cmolckg^{-1} in B horizon of profile 1 of the subsurface horizons. According to rating set by FAO (2006), the concentration of exchangeable Mg observed in all surface horizons are categorized as high levels. The level of magnesium in the soils was high indicating the presence of sufficient magnesium in the soils of the study area.

Exchangeable potassium of the soil in the study area was ranged from 0.70-1.39, 1.31-7.04 and 1.21-4.06 cmolckg^{-1} in which profiles 1, 2 and 3 respectively (Table 5). It was relatively higher than Na in surface horizon of all profiles. The contents of exchangeable K at the surface horizons varied from 1.15 cmolckg^{-1} (Profile 1) to 3.88 cmolckg^{-1} (Profile 3). The exchangeable K in subsurface horizons ranged from 0.70 cmolckg^{-1} C horizon of profile 1 to 7.04 cmolckg^{-1} bottom subsurface of profile 2. The exchangeable K in the study area increased systematically down topographic position and increased unsystematically with depth of profile except in profile 1. The increment of exchangeable K down topographic position and with depth could be due to downward movement by erosion and leaching. According to rating set by FAO (2006), the concentration of exchangeable K observed in all surface profiles was categorized as high to very high levels. The result agrees with the common idea that Ethiopian soils are rich in K.

The amount of exchangeable Na of soil in the study area was ranged from 0.08-0.2, 0.26-1.39 and 0.28-1.23 cmolckg^{-1} in profiles 1, 2 and 3 respectively (Table 5). It varies from 0.08 cmolckg^{-1} (Profile 1) to 0.28 cmolckg^{-1} (Profile 3) in the surface horizon and from 0.1 cmolckg^{-1} C horizon of profile 1 to 1.39 cmolckg^{-1} in B_{t2} horizon of profile 2 in the subsurface horizons. The highest amount of exchangeable Na (1.39 cmolckg^{-1}) for subsurface horizon was recorded in bottom subsurface of profile 2. Exchangeable Na in the study area consistently increase down topographic position and increase with depth in most profiles. This could be due to downward movement by erosion due to slope gradient and leaching to subsurface by rainfall. According to rating set by FAO (2006), exchangeable Na was very low to high throughout the profiles and horizons of the studied soils.

Generally, principal cations occupying the exchange site were in the order of $Ca^{2+}>Mg^{2+}>K^{+}>Na^{+}$. The exchangeable base of soils in the study area was mostly saturated with Ca^{2+} followed by Mg^{2+}, K^{+} and Na^{+}. This might have resulted from the strong energy of adsorption of Ca, making it typically more abundant as an exchangeable cation than Mg, K or Na (Foth, 1990). Calcium is more strongly adsorbed than Na because it is a divalent cation.

Simple linear correlation analysis

Simple linear correlation analysis was carried out in order to explore the magnitude and direction of relationships among the soil physicochemical properties in the study area. The results showed that certain attributes of soil showed significant relation with each other, whereas others did not show any significant form of relationships among themselves. From physical properties, there were highly significant and negative correlation between sand and clay contents (r=-0.813**), which might simply be due to movement of fine particles down the topographic position and leaching of clay down the depth of profiles and on site accumulation of sand particles. In agreement with this result, Sheleme (2011) reported that the susceptibility of fine particles by erosion cause the increment of clay particles down the topographic position. Soil reaction (pH) was highly significantly and positively correlated with EC (r=0.838**), Na (r=0.940**) and K (r =

Table 6. Correlation coefficient for selected soil physical and chemical properties of soils of the study area.

Par	Sand	Clay	pH	E.C	Bd	P%	TN	Av.P	OM	Ca	Mg	Na	K	CEC	PBS
Sand	1														
Clay	-0.813**	1													
pH	-0.126	0.305	1												
E.C	-0.033	0.166	0.838**	1											
Bd	0.160	0.047	0.637*	0.431	1										
P%	-0.143	-0.069	-0.646*	-0.440	-0.999**	1									
TN	-0.181	-0.258	-0.510	-0.326	-0.558	0.563	1								
Av.P	-0.130	-0.178	-0.465	-0.294	-0.556	0.567	0.755**	1	*						
OM	-0.160	-0.290	-0.534	-0.318	-0.545	0.551	0.995**	0.734*	1						
Ca	-0.632*	0.560	0.537	0.570	0.281	-0.292	0.039	-0.120	0.043	1					
Mg	-0.677*	0.549	0.230	0.259	-0.168	0.170	0.167	0.063	0.174	0.770**	1				
Na	-0.100	0.337	0.940**	0.746**	0.624*	-0.636*	-0.576	-0.533	-0.604*	0.521	0.141	1			
K	-0.337	0.441	0.803**	0.819**	0.374	-0.376	-0.263	-0.057	-0.270	0.701*	0.522	0.740**	1		
CEC	-0.560	0.405	0.252	0.361	0.124	-0.134	0.389	0.044	0.399	0.889**	0.670*	0.246	0.452	1	
PBS	0.133	0.047	0.446	0.375	0.174	-0.169	-0.668*	-0.137	-0.677*	-0.099	-0.039	0.406	0.424	-0.523	1

0.803**). Electrical conductivity was highly significant with K (r=0.819**) and Na (r=0.746**). The incremental of pH with depth show accumulation of most exchangeable bases in subsurface horizons of the soil. Bulk density was highly significant, negatively correlate with porosity (r=-0.999**) and positively correlate with Na (0.624*), whereas porosity was significant and negatively correlate with Na (-0.636*). Because of high OM in surface than subsurface soil, the pore space also high in surface and bulk density become low, whereas OM is high in the soil. Thus, the increment of bulk density cause reduction of porosity of the soil and show negative relationship between them. The content of total N was significantly and positively correlated with organic matter (0.995**) and available P (0.755**) (Table 6). This is an indication of the direct dependence of total nitrogen content on the content of soil organic matter. Therefore, in the management of total nitrogen, it may be imperative to maintain and increase the level of soil organic matter and also apply P content fertilizers. Organic matter content was significant and negatively correlate with Na (r=-0.604*) and PBS (r=-0.677*). Exchangeable Ca was significantly and positively correlated with exchangeable Mg (r=0.774**) and CEC (0.889**). The positively correlated of exchangeable Ca with CEC indicates their respective major contributions to the CEC of the soil in the study area.

Soil classification

Classification of the soil was done according to the standard procedures of World Reference Base for soil resource (FAO, 2014). Depending on physiochemical and morphological data obtained from the opened profiles, the soil of Jello Chancho watershed was classified under Abruptic Luvisols (profile 1), Haplic Luvisols (profile 2) and luvic Phaeazems (profile 3).

According to FAO soil classification guideline (FAO, 2014), soil profile 1 can be classified as Luvisols. The profile 1 was opened on shrub land of upper slope position, where there was higher clay content in the subsurface soil than in the surface soil. Movement and build-up of clay formed *argic* subsoil horizon. Soils with high clay activity throughout the *argic* horizon and a high percentage base saturation in the 50-100 cm depth satisfy the definition of Luvisols as a reference soil group. The argic horizon has a clay content >8% than the underlying layer and the clay content is double than the underlying to fulfill Abuptic qualifiers. According to those set of principles, the subsurface soil could be identified as and qualified for Abruptic principal qualifiers. However, the presence of a percentage base saturation of 50% or more throughout between 20 and 100 cm from soil surface, and 80% or more in some horizons within 100 cm of soil surface fulfils the criteria of Hypereutric supplementary qualifiers at the result of those soils that were identified and classified as Abruptic Luvisols (Hypereutric).

Profile 2 was opened on the cultivated land at the middle slope position, where there was higher clay content in the subsurface soil than in the surface soil. The movement and accumulation of clay formed argic subsoil horizon. Soil with high clay activity throughout the argic horizon and high percentage of base saturation in the 50-100 cm depth satisfy the definition of Luvisols as a reference soil group.

These characteristics entirely define the soil without the requirement of other principal qualifier and thus *Haplic* was prefixed. However, the presence of a percentage base saturation of 50% or more throughout between 20 and 100 cm from soil surface and 80% or more in same layer within 100 cm of soil surface fulfills the criteria of Hypereutric supplementary qualifiers; as a result, those soils were recognized and classified as Haplic Luvisols (Hypereutric).

Finally, profile 3 was excavated in the lower slope position in grass land of the study area. So, by taking into consideration physiochemical and morphological properties of the soil, profile 3 was categorized as luvic Phaeozems. As defined by FAO (2014), Phaeozems has percentage base saturation 50% or more and has no secondary carbonate to at least a depth of 100 cm from the top soil. According to the criteria set by FAO (2014) soil classification guideline, the subsurface could be identified as Phaeozems. Therefore, the soil of profile 3 was categorized as Phaeazems at reference group level. The subsurface horizons of profile 3 has an arglic horizons by starting ≤100 cm from the soil surface having cation exchange capacity greater than 24 in subsurface and percentage base saturation more than 50% which qualify to identify it as luvic principal qualifiers. In the case of supplementary qualifiers, the profile showed PBS of 50% or more throughout between 20 and 100 cm from the soil surface and 80% or more in some layer within 100 cm of the soil surface and it fulfilled the criteria of Hypereutric supplementary qualifiers; as a result, those soils were recognized and classified as Luvic Phaeazems (Hypereutric).

Conclusions

Achievement in soil management to maintain soil quality depends on the understanding of how soils respond to agricultural use and practice over time. This indicates that understanding the characteristics and classification of soils is best requirement for designing appropriate management strategies thereby solving many challenges that are facing the crop and livestock production sectors and in their efforts towards natural resource conservation, decision making, planning and policy formulation and management for sustainable development. Understanding of soil physiochemical properties is useful for proper utilization of soil resource and hastening technology transfer. In view of this, a study was conducted on soils of Jello Chancho Watershed in Liban District, East Shewa Zone of Ethiopia to characterize the physicochemical properties and classification of soil.

The physiochemical and morphological properties of the soils showed variation along the topographic positions, land uses and soil depth. The soil represented by profile 1 in the upper slope position was moderately deep whereas the profiles in the middle and lower slope positions were deep. The color surface horizons were dark reddish brown, dark gray brown and black in profiles 1, 2 and 3 respectively. The structures were granular with friable moist consistence in surface horizons of all profiles. In the case of particle size distribution, the contents of sand decrease unsystematically down the topographic position and also decrease with the depth of profiles unsystematically while the contents of clay increases with depth of the profiles and down the topographic position irregularly. The textural classes of surface soil were loam in upper and middle slope position and changed to clay loam as the percentage clay content increase down topographic position. The bulk density of the soil showed inconsistent relationship with topographic position and increase unsystematically with the depth of all profiles.

The pH of the soil increased systematically with depth of the profiles, unsystematically increased down the topographic position of the study area and rated as moderate acid to neutral. The organic matter content of the soil in the study area decreased with depth of all profiles. The total nitrogen also showed the variation within and among profiles to the level of organic matter. It is categorized under high in upper slope, medium in middle slope and high in lower slope position of surface soil. Available phosphorous, exchangeable bases, CEC and PBS have inconsistent relationship with depth of soil profile and topographic position. Based on the morphological and physicochemical data obtained from the opened profiles, the soil of the study area was categorized under Abruptic Luvisols in profile 1 (upper slope), Haplic Luvisols in profile 2 (middle slope) and luvic Phaeozems in profile 3 (lower slope).

Some soil nutrients indicators such as organic matter contents, available phosphorous, total nitrogen and other nutrients of cultivated land was rated as low and very low in the soil of the Jello Chancho Watershed and these should be managed by application of crop residue, compost, green manure and farmyard manure in order to improve agricultural potential of soils of the Jello Chancho Watershed. Especially, the soil test of Jello Chancho Watershed of Av. P was rated low and very low which should be improved by applying organic materials and P-fertilizers to maximize agricultural production. There was less soil water conservation practice in the Jello Chancho Watershed. So, to mitigate the nutrients deficiency in the study area, constructing of SWC measures is the main requirement.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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APPENDIX

Table 1. Description of the soil site and soil profile opened at the upper slope.

Profile number	1
Soil classification	Abruptic Luvisols
Date of examination:	15 March, 2018
Author of description:	Abu Regasa
Location:	Jello No-5, Jello Chancho Watershed, East Shewa Zone, Ethiopia
Coordinates	8° 35’17’’N latitude and 39° 2’25’’E longitude
Altitude:	1969 m above sea level
Surrounding landform:	Slightly hilly to the north
Physiographic position:	Upper
Slope:	Strongly sloping with about 12% slope gradient
Moisture condition:	Dry soil
Drainage:	Well drained
Ground water table:	Not encountered, most probably very deep
Parent material:	Colluvial material
Erosion status:	Moderate
Rock outcrops/stoniness:	Very few
Present land use type:	Shrub land
Natural vegetation:	Every green shrubs

Depth (cm)	Horizon	Description
0-26	A	5YR3/3 dark reddish brown moist, 2.5YR4/3 dark reddish brown dry; moderate, medium, granular; slightly hard, friable, slightly stick and plastic; loam; non-calcareous; clear smooth boundary to,
26-47	B	2.5YR3/4 dark reddish brown moist, 10YR4/3 brown in dry; medium to strong, medium, prismatic; hard, firm, stick and plastic; clay loam; non-calcareous; clear smooth boundary to
47-81	C	7.5YR8/2, pinkish white moist and the same in dry; strong, very course, angular blocky; hard to very hard, friable, non-stick and non-plastic; loam; non-calcareous.

Table 2. Description of the soil site and soil profile opened at the middle slope.

Profile number:	2
Soil classification	Haplic Luvisols
Date of examination	17 March, 2018
Author of description:	Abu Regasa
Location:	Jello No-4, Jello Chancho Watershed, East Shewa Zone, Ethiopia
Coordinates	8° 33’ 48’’ N latitude and 39° 2’ 37’’ E longitude
Altitude:	1714 m above sea level
Surrounding landform:	Level land
Physiographic position:	Middle slope
Slope:	Very gentle sloping with about 2% slope gradient
Moisture condition:	Dry soil
Drainage:	Well drainage
Ground water table:	Not observed up to 107 cm depth
Parent material:	Alluvial material
Erosion status:	None at site with slight sheet erosion in the surrounding
Rock outcrops/ stoniness:	None
Present land use type:	Cultivated land
Natural vegetation:	No vegetation at site with some woodland trees in the surrounding

Table 2. Contd.

Depth (cm)	Horizon	Description
0-21	Ap	Very dark grayish brown(10YR3/1) moist, dark gray brown (10YR4/2) dry; weak, fine, granular; soft, friable, slightly stick and slightly plastic; loam; non-calcareous; clear smooth boundary to
21-33	AB	Very dark gray (7.5YR3/1) moist, grayish brown (10YR5/2) dry; moderate, medium, granular structure; slightly hard, firm, slightly stick and plastic; loam; non-calcareous; clear smooth boundary to
33-59	Bt1	Dark gray (7.5YR4/1) moist, very dark gray (10YR3/1) dry; strong, very coarse, subangular prismatic; hard, very firm, very sticky and very plastic; clay; non-calcareous, clear smooth boundary to
59-107	Bt2	Dark reddish brown (5YR3/2) moist, yellowish brown (10YR5/6) dry; moderate, course, subangular blocky; hard, firm, sticky and plastic; loam; non-calcareous.

Table 3. Description of the soil site and soil profile opened at the lower slope.

Profile number:	3
Soil classification	Luvic Phaeazems
Date of examination:	18 March, 2018
Author of description:	Abu Regasa
Location:	Gici Chancho, Jello Chancho Watershed, East Shewa Zone, Ethiopia
Coordinates	8° 31' 42'' N latitude and 39° 0' 45'' E longitude
Altitude:	1678 m above sea level
Surrounding landform:	Flat
Physiographic position:	Lower slope
Slope:	Flat land with about 0.1% slope gradient
Moisture condition:	Dry soil
Drainage:	Weakly drainage
Ground water table:	Not observed up to 200 cm depth
Parent material:	Alluvial deposit
Erosion status	None
Rock outcrops/stoniness:	None
Present land use type:	Grassland
Natural vegetation:	Vegetation cover by woodland trees here and there

Depth (cm)	Horizon	Description
0-24	A	Black (10YR2/1) moist, dark gray (10YR4/1) dry; strong, very course, granular; slightly hard, friable, sticky, and very plastic; clay loam; non-calcareous; abrupt smooth boundary to
24-43	AB	Dark grayish brown (10YR4/2) moist, gray (7.5YR6/1) dry, weak fine prismatic structure, slightly hard, firm, slightly sticky and plastic consistency, loam texture, non-calcareous, clear smooth boundary to
43-137	Bt1	Very dark brown (7.5YR2.5/2) moist, very dark gray (7.5YR3/2) dry; moderate, medium, prismatic; very hard very firm, very sticky and very plastic; clay; non-calcareous, clear smooth boundary to
137-200	Bt2	Dark yellowish brown (10YR4/4) moist, yellowish brown (10YR5/6) dry; moderate, medium, subangular prismatic; hard, firm, sticky and plastic; loam; non-calcareous.