Research Article

Open Access CrossMark

Assessment of the pysicochemical status soils and irrigation water qualities in eastern Ethiopia

Volume 3 Issue 3 - 2019

Assefa Adane,[1] Heluf Gebrekidan,[2] Kibebew Kibret[2]

[1]Kotbe Metropolitan University, Ethiopia
[2]Haramaya University, School of Natural Resources Management and Environmental Sciences, Ethiopia

Correspondence: Assefa Adane, Kotbe Metropolitan University, Post Of Box 31248, Addis Abeba, Ethiopia, Email assefatsion@gmail.com

Received: August 12, 2019 | **Published:** September 30, 2019

Abstract

This study intended to characterize the physicochemical characteristics of soils and irrigation water qualities under four land use types of Babile low lands in eastern Ethiopia. Four profiles opened from non-cultivated (profile 1), two irrigated cultivated (profile 2 & 3) and none irrigated cultivated lands (profile 4) for laboratory analysis. The results revealed relatively variation in morphological and physicochemical properties of soils. The soils are clay to sandy in texture with bulk density values ranging from 1.12 to 1.32gcm^{-3} and the clay contents significantly affected both by land use type and profile depth. The basic infiltration rates and saturated hydraulic conductivities of the soils were moderately slow. The soils were moderately alkaline to alkaline in reaction (pH 7.89 to 8.54), the mean soil electrical conductivity of saturated pest (ECe) were greater than 4dSm^{-1} and significantly affected by land use type and profile depth. The exchangeable cations determined had clear distinctions on the distribution of adsorbed cations; adsorbed Na^+ was higher on the exchange site of the irrigated soils than the non-irrigated soils. Medium to very high cation exchange capacity (34.26 to 38.92cmol$_{(+)}$ kg^{-1}) was recorded. Exchangeable cations (Na, K, Ca, Mg), Exchangeable sodium percentage (ESP), sodium adsorption Ratio (SAR) and Cation Exchangeable Capacity (CEC) were significantly ($P<0.05$) affected by land use types and profile depth. In line with this, two irrigation water sources were analyzed, the result revealed that both water sources contained medium to very high dissolved salts. On the other hand, the residual sodium carbonate (RSC) of Errer River (1.25 to 2.50meqL^{-1}) and ground waters (>2.50meqL^{-1}) were marginal and unsafe for irrigation, respectively. It could therefore be generalized that, beside to natural conditions, irrigation water could be the main source for the occurrence of saline sodic soils in the irrigated lands of the area. Hence, introduction of locally available organic and inorganic reclaiming materials may improve the productivity of the saline sodic soils of the study area for the resource poor farmers.

Keywords: profile, morphology, soil classification, soil salinity/sodicity

Abbreviations: ECe, electrical conductivity of saturated pest; ESP, exchangeable sodium percentage, ESP, exchangeable sodium percentage; SAR, sodium adsorption Ratio; CEC, cation exchangeable Capacity; FC, filed capacity; PWP, permanent wilting point, AAS, atomic absorption spectrophotometry; CEC, cation exchange capacity, Av.P, available phosphorous; AWHC, available water holding capacity; SOC, soil organic carbon; ESP, exchangeable sodium percentage; AAS, atomic absorption spectrophotometry

Introduction

Saline sodic soil is one of the most important soil factors which affect plant growth and ultimately limit crop production and productivity.[1–3] Studies conducted in different areas estimated that nearly 11million hectare (ha) of soils in Ethiopia is in the grip of salinity and sodicity hazard.[4] As a result, salinity/sodicity of soil is becoming a serious threat to crop production in the arid and semi arid areas of Ethiopia.[5–8]

Land use change particularly from natural ecosystem to agricultural lands in general and to irrigated crop production under poor management practices in particular are among the major causes of declining in soil fertility followed by land degradation and low agricultural productivity.[9,10] Hence, assessing soil physicochemical properties is imperative to understand the status of soil quality in different land uses. Maintaining soil quality mainly depends on the characterization of the physicochemical properties of a given soil. Soil characterization is required to classify soils, and determine chemical and physical properties not visible in field examination.[11] Therefore, knowledge of the kinds and properties of soils is critical for decisions making with respect to soil management and crop production.[12,13]

Salt affected soils occurred either from parent material in areas where evapotranspiration exceeds mean rain fall or from soils treated with poor irrigation management practices. Crop production in arid and semi arid regions is dependent on irrigated agriculture.[14] However, the hot and dry climates of these regions require that the irrigation water should not contain soluble salts in amounts that are harmful to plants or have adverse effects on soil properties. However, water of such quality is not available in sufficient quantities to satisfy the water requirement of all the crops grown. Under this condition farmers are forced to use all irrigation water sources.

Irrigated land in Ethiopia is estimated only 4 to 5%, covering about 640,000 ha, which is a significant portion of cultivated land is currently not irrigated.[15] The annual rainfall in study area is less than the evapotranspiration rate and then farmers fulfill their crop water requirement from Rivers and ground water sources. However, both water sources contained medium to very high concentration of dissolved salts sufficient enough to gradually develop salt upon continuous use for irrigation,[8] which, in turn, required expensive treatment to make them productive again. Therefore, a well-managed irrigation development system could overcome major challenges of low agricultural productivity resulted due to irrigation.[15]

Similar to the other arid and semi-arid regions of Ethiopia, severe soil salinity/sodicity problem has been reported recently in the Babile District, eastern Ethiopia.[8] However, the degree, extent and causes of the problem had not been yet examined. Basic information on the distribution, extent and causes of soil salinity/sodicity in the Babile low lands could assist policy makers, researchers, extension workers and farmers as baseline information to improve the fertility and productivity of the soils of the area as well as elsewhere in the country with similar agro ecology. This study was conducted, therefore, to determine the physicochemical characteristics, extent of salinity/sodicity of soils and irrigation water quality in Babile, eastern Ethiopia.

Materials and methods

General description of the study area

The study area, Baile District, is located at about 30 and 90km, respectively, from Harar and Jijiga towns in the Oromia Regional State, Eastern Ethiopia (Figure 1). The District lies between 08^0 21' and 09^0 11' N latitude and 42^0 15'-42^0 55'E longitude with an altitude range of 900-2000 meters above sea level (masl). According to the Ethiopian agro climatic zonation,[15] the study area falls in the lowland region. The ten years (2002-2012) climatic data of Bisidimo area indicated an average annual rainfall of 650mm which is characterized by bimodal rainfall pattern. The annual mean maximum and minimum temperatures for the same period were 30.9 and 23.5^{0}C, respectively.

According to FAO,[16] classification, the major soil types found in the District are Regosols and Arenosols, Leptisols, Luvisols and its association, and Fluvisols and its association. The soils are dominantly sandy loam; however, some pocket areas of the District are dominated by clay and clay loam textures. The major crops grown by farmers include maize (*Zea mays* L.), sorghum (Sorghum bicolor), groundnut (*Arachis hypogae*) and haricot beans. Sorghum, maize and haricot bean are cultivated for food consumption; whereas, groundnuts and chat are grown as cash crops. Crop production is based on rain fed agriculture and harvested usually once in a year. However, farmers in Bisidimo area practiced irrigation agriculture using the Errer River and ground water sources. Agricultural production in the District is constrained by small land holdings, high price of inputs and inadequate credit service along with shortage of rain/water and salinity/sodicity development in the soil. The livestock raised includes cattle, camel, goats and donkeys. The major vegetation groups found in the study area includes woodland, acacia, bush and shrub.

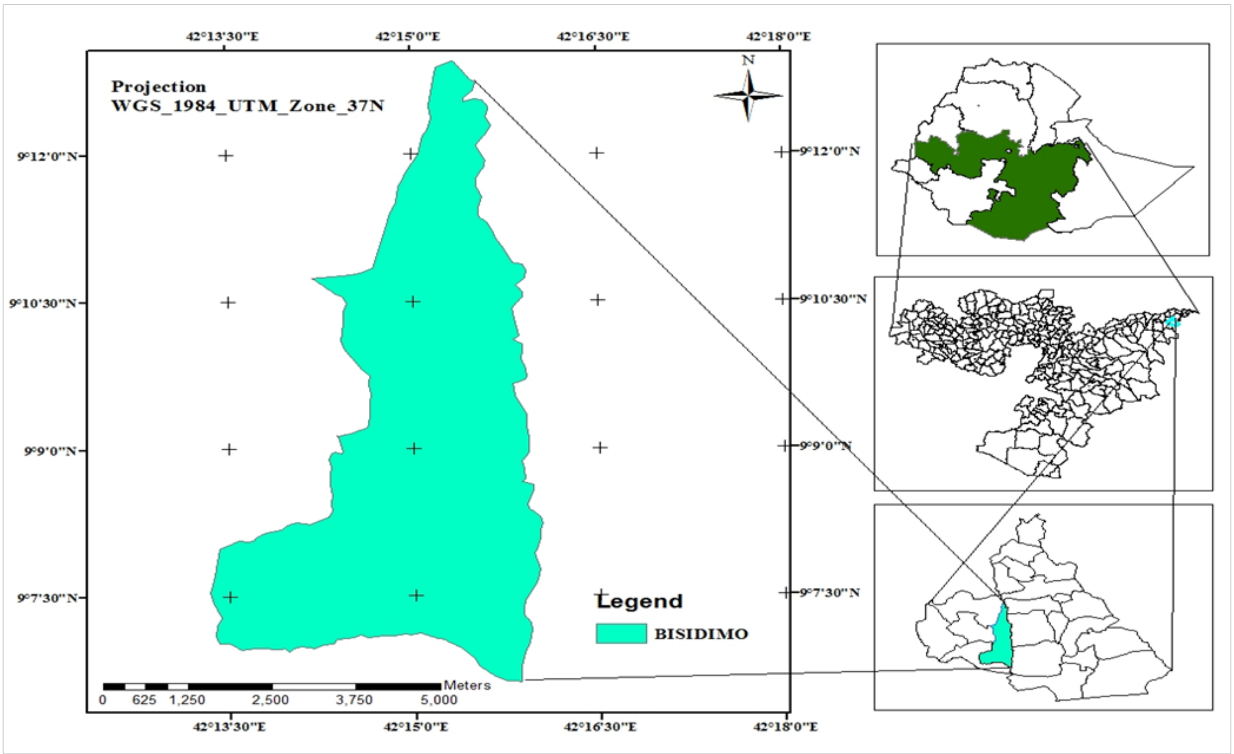

Figure 1 Map of Babile District and location of the study area (Bisidimo area).

Soil sampling and sample preparation

In order to have general information about the land forms, land uses, topography and vegetation cover, a preliminary survey and field observation was carried out during the year 2011 using the topographic map (1:50,000). Accordingly, four representative study sites representing different cultivation histories (non cultivated or grazing land, non-irrigated maize farm and two irrigated maize farms) were selected. On each land use, one fresh profile was opened and the soil profiles were described at the field. All important morphological and physical properties were recorded at the field. Field observation, profile excavation, description and horizon differentiation were carried out according to the FAO guidelines for soil profile description.[17] Soil samples were collected on generic horizon basis for characterization of selected physicochemical properties.

Citation: Adane A, Gebrekidan H, Kibret K. Assessment of the pysicochemical status soils and irrigation water qualities in eastern Ethiopia. *Forest Res Eng Int J.* 2019;3(3):91‒104. DOI: 10.15406/freij.2019.03.00085

Laboratory analysis

The soil samples were air dried ground and passed through 2mm sieve for analysis. Soil particle size distribution was analyzed by the Bouyoucos hydrometer method as described by Day.[18] Bulk density (Bd) was determined from undisturbed (core) soil samples collected using core samplers, weighed at field moisture content and then dried in an oven at 105^{0}C. Particle density (Pd)=2.65gcm^{-3} which is the value of most mineral soils was taken for total porosity calculation. Total porosity of the soils was estimated as follows

$$\text{Total porosity}\left(\%\right)=\left(1-\frac{Bd}{pd}\right)100$$

The moisture content at filed capacity (FC) and permanent wilting point (PWP) was measured at soil water potential of -1/3 and -15 bars, respectively, using the pressure plate apparatus; whereas available water holding capacity (AWHC) was determined by finding the difference between moisture percent at FC and PWP.[14] Soil organic carbon (SOC) was determined by wet oxidation method.[19] Total nitrogen (N) in the samples was determined by the modified Kjeldahl method,[20] and determination of available phosphorous (Av.P) was carried out by the Olsen method using sodium bicarbonate (0.5M $NaHCO_3$) as extraction solution.[21]

Soil reaction (pH) and electrical conductivity of the saturated paste extract (ECe) were measured in 1:1 soils: water suspension using pH meter and conductivity meter, respectively. Exchangeable bases were extracted with 1.0 molar (M) ammonium acetate solution at pH 8.2. Sodium and K contents in the extract were determined by flame photometry while Ca and Mg contents were obtained by atomic absorption spectrophotometry (AAS) from the same extract. Similarly, soluble Na and K ions were determined by flame photometry, while Mg and Ca ions were determined by atomic absorption spectrometry. Cation exchange capacity (CEC) was estimated from the sum of exchangeable cations. Sodium adsorption ratio (SAR) was computed from the data of chemical analysis. Exchangeable sodium percentage (ESP) was calculated by using the equation below:

$$ESP=\left(Na\left(cmol\left(+\right)kg\ of\ soil\right)/\left(CEC\left(cmol\left(+\right)kg\ of\ soil\right)\right)\right)X100$$

Sodium adsorption ratio (SAR) of the soil solution was calculated from the concentration of soluble cations (Na^+, Ca^{2+} and Mg^{+2}) as follows:

$$SAR=\left(Na\left(cmol\left(+\right)/\ kg\ of\ soil\right)/\left(\sqrt{\left(Ca+Mg\right)}\right)/\ 2\right)$$

Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) concentrations were determined from the saturated soil paste extract by simple acidimetric titration using phenolphthalein indicator for CO_3^{2-} (pH>8.5), and methyl orange for HCO_3^- (pH<6.0). The extract with a mixture of these indicators was titrated by standard 0.01N H_2SO_4 to phenolphthalein and methyl orange end points for CO_3^- and HCO_3^- contents, respectively.[22] Chloride ion (Cl^-) were determined by titrating the aliquot used for carbonate and bicarbonate determinations using silver nitrate to potassium chromate end point as described by Hesse.[22] Nitrate (NO_3^-) content of the soils was analyzed as per the method outlined by Okalebo et al.[23] but the concentration was nil throughout all profiles. In addition, sulphate ions in soil samples were determined gravimetrically by precipitating as barium sulphate ($BaSO_4$) as described by FAO.[24] Soil classification was based on the World Reference Base Soil Classification System.[25]

Water sampling and analysis methodologies

Irrigation water samples from three ground water sources and Errer River were collected once in January 2012 for chemical analysis. The collection and handling of the irrigation water samples was done in accordance with the procedures outlined by the U.S. Soil Salinity Laboratory Staff.[26] The pH and EC of the irrigation water was determined using pH and EC meters, respectively. Soluble cations (Na^+, K^+, Mg^{2+} and Ca^{2+}), and anions (Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-} and NO_3^-) in the irrigation water samples were determined following the procedures as described for respective determination of the saturated soil paste extracts. Sodium adsorption ratio (SAR) of the irrigation water was calculated using this equation:-

$$SAR=\left(Na\left(cmol\left(+\right)/\ kg\ of\ soil\right)/\left(\sqrt{\left(Ca+Mg\right)}\right)/\ 2\right)$$

Similarly, residual sodium carbonate (RSC) content of the irrigation water samples was calculated as RSC=(CO_3^{2-}+HCO_3^-)–(Ca^{2+}+Mg^{2+}), where concentrations of all constituents are given in melliequivalent (meqL^{-1}). All analysis of the soil and irrigation water was made in triplicate samples. Therefore, data of chemical properties thereof presented in the result and discussion are average of three repeated analyses results.

Field infiltration measurement

A double ring infiltrometer with inner and outer rings of 20 and 30cm diameter, respectively, was used to determine steady infiltration rate at a constant head. A steel pointer was positioned at the center of the inner cylinder with 3cm height above the soil surface. The inner cylinder was then filled with water equivalent to a 4cm water head initially. The time taken to drop the water level in the inner cylinder to the pointer was recorded. Thereafter, a measured volume of water was filled successively and the time taken to infiltrate this amount was recorded. When the amount of water entered into the soil did not change with time for three consecutive measurements taken at 5-minute intervals, steady state flow was assumed and steady state infiltration rate was calculated based on the last three measurements.

A Guelph permeameter was also used to measure the cumulative water flux under surface ponding conditions. The Guelph permeameter tests lasted at about 30-50minutes. One measurement was taken on each land use. The Ksat was calculated and then estimated according to Reynolds et al.[27]

$$K_{sat}=CQ/\left(2\pi H2+2\pi a2C+\left(2H\pi/\alpha G\right)\right)$$

where Q is steady water flux [L^3 T^{-1}], H is the ponding depth [L] (5cm), a is the well radius [L] (3cm), α_G=12m^{-1}, C is the constant characterizing soil structure [L^{-1}] and it is dimensionless constant calculated according to the following equation:-

$$C=\left[\left(H/a\right)/\left(2.074+0.0093\left(H/a\right)\right)\right]^{0.754}$$

Data analysis

General Linear Model (GLM) procedure,[28] version 9.2 was employed to analyze the correlation among soil parameters and water samples.

Results and discussion

Characterization of soils and irrigation water quality

Soil morphological properties: Soil sampling sites and field

Citation: Adane A, Gebrekidan H, Kibret K. Assessment of the pysicochemical status soils and irrigation water qualities in eastern Ethiopia. *Forest Res Eng Int J.* 2019;3(3):91‒104. DOI: 10.15406/freij.2019.03.00085

description of morphological features of the soil profiles presented in (Table 1) exhibited variation in soil depth, particle size distribution, structure and color. The variation could be due to the difference in parent material or land use change.[29] The moist colors of the surface and sub surface horizons of profile 1 generally varied from brown (10YR 5/4 to dark brown (10YR 4/3) (Table 1). However, the dry colors of the soils throughout the lower layers were dark grayish brown (10YR 4/4). Similarly, the moist and dry colors of the surface and sub subsurface layers of profile 2 varied between brown (10YR 2/1 and very dark brown (10YR 3/1) color. In line with profile 1 and 2, the moist and dry colors of the surface and sub surface layers of profile 3 varied between brown (10YR 3/1) and very dark brown (10YR 3/1) colors. On the other hand, the profile studied representing by profile 4 showed the moist and dry hues of 7.5YR throughout its horizons. Accordingly, the colors of this profile varied between light brown (7.5YR 3/2) and dark brown (7.5YR 3/1) at the respective moisture levels (Table 1). In conclusion, the moist and dry colors of the soil in all profiles almost varied between brown and very dark brown which could be due to the imperfectly drainage conditions of the soils and/or declining effect of organic matter in the area. However, the soil color may be affected by integrated outcome of various factors like organic matter and soil redox environments.[30]

On the other hand, the structure of the soils in the area showed slight variations from surface to subsurface horizons reflecting that there was a slight variability in the development of soil structures (Table 1). Accordingly, the structures of the soil in profile 1 are weak, fine to medium angular blocky in the 1st layer and strong sub angular blocky in the 2nd layer. The subsurface horizons changed from moderate sub-angular blocky to strong angular blocky structure in the middle and lower horizons (Table 1). Similar findings were reported by Mohammed et al.[31] in the soil of Jillo catchment, West Hararghe, according to him strong angular and sub-angular blocky structures might possibly reflect the low contents of soil OC, the existence of high clay content and probably the presence of expandable clay minerals such as montmorillonite.

On the other hand, the soil consistence of profile 2 was slightly friable (moist), slightly sticky and slightly plastic (wet) at the surface layer (0-20cm) and changed to very hard friable (moist), sticky and plastic (wet) at the 20-35cm and to very hard, firm (moist), sticky and plastic at the 35-95cm and very hard, friable, firm, sticky and plastic at the extreme bottom subsoil layer (95-150+cm). The horizon boundaries in profile 2 were clear and smooth in the 1st layer, gradual and smooth in the 2nd layer while, clear and wavy boundaries observed in the 3rd and 4th layers.

The soil consistence of profile 3 was hard, very friable, slightly sticky and slightly plastic at the surface (0-15cm) changed to slightly hard, friable, sticky and plastic at the interval between 15-55cm depth while the lower two depths (<55cm) were very hard, friable, sticky and plastic. The surface (0-15cm) and sub surface (15-55cm) horizons in this profile had gradual and smooth boundary, however, gradual and wavy boundary characterized the remaining lower bottom layers. The root distribution of profile 3 was many fine in the surface layer (0-15cm) to common fine at the 2nd and 3rd (15-55 and 55-90cm) layers and none at the extreme bottom layer (90-150+cm) (Table 1).

The soil consistence of surface (0-35cm) layer of profile 4 was hard, friable and slightly sticky and slightly plastic changed to hard, friable, sticky and plastic in the 35-90cm layer, very hard, very friable and sticky and plastic at the 90-130cm layer and very hard, firm, sticky and plastic in the bottom (130-160+cm) layer. The root distribution was characterized by many medium and coarse at 0-35cm to few fine at 35-90cm, few very fine at 90-130cm and none at the bottom layer (130-160+cm) (Table 1). Soils in profiles 1,2 and 3 exhibited intersecting and shining slickenside and wide closely-spaced cracks. The cracks observed in the dry season were closed in the wet season, showing the existence of soil contraction and expansion, respectively. The presence of varying gradient of cracks and slickenside indicated that the soils of the study area had variable degrees of vertic properties and revealed the existence of appreciable amount of expandable clay mineralogy.[32]

In all profiles, the presence of more pores in the surface layers than in the subsurface layers indicated more roots and higher number of soil organisms in the former soil layers than in the latter (Table 1). The distribution of roots also varied from abundant fine to very fine and common medium at the surface layer to very fine and very few at the subsoil horizons. The abundance and size of roots and the size of pore spaces (macro pores) decreased down the profile depths. No effervescence was observed in all the profile depths with the addition of dilute (10%) HCl, indicated the absence or very low content of calcium carbonate.

Table 1 Field descriptions of selected soil morphological properties of Bisidimo area

Profile	Depth (cm)	Boundary[1]	Color	Structure[2]	Consistency[3]	Roots	Special features
	0-30	GS	10YR 4/3	1fmgr	frstp	Many fine	Vertical cracks, fine pores
	30-65	GS	10YR 4/3	4 sbk	hfistpl	Many fine	Vertical cracks, many fine pores
1	65-100	CS	2.5YR 3/1	3 mgr	hfrstp	Few fine	Vertical cracks, many fine pores
	100-130	CS	5YR 5/4	2 fmsbk	slhfrslstslp	None	Common coarse pores
	130-150+	CS	2.5YR 3/1	3 csabk	slhfrslstslp	None	Common coarse pores
	0-30	CS	10YR 4/3	1fmgr	slfrslstslp	Many fine	Hard surface crust, vertical cracks, fine pores
2	30-55	GS	10YR 3/1	2msbk	vhfrstp	Common fine	Intersecting and shining slickenside and wide cracks
	55-95	CW	10YR 4/6	3cssbk	vhfistp	Few fine	Intersecting and shining slickenside and wide cracks
	95-150+	CW	10YR 3/1	3csabk	vhfrfistp	None	Intersecting and shining slickenside and wide cracks
	0-35	CS	10YR 3/1	1fmsbk	hfrslstslp	Many fine	Wide closely-spaced cracks
3	35-70	GS	10YR 5/4	2msbk	hfrstp	Common fine	Intersecting and shining slickenside and wide cracks
	70-90	GW	10YR 6/2	3cssbk	vhfrstp	Common fine	Intersecting and shining slickenside and wide cracks
	90-150+		10YR 3/1	3cssbk	vhfrstpl	Few fine	Intersecting, shining slickenside and wide cracks
	0-15	CS	7.5YR 5/4	3csgr	hfrslstslp	Many medium	Narrow vertical cracks, fine pores

Citation: Adane A, Gebrekidan H, Kibret K. Assessment of the pysicochemical status soils and irrigation water qualities in eastern Ethiopia. *Forest Res Eng Int J.* 2019;3(3):91‒104. DOI: 10.15406/freij.2019.03.00085

Table Continues...

Profile	Depth (cm)	Boundary[1]	Color	Structure[2]	Consistency[3]	Roots	Special features
4	15-60	GS	7.5YR 5/4	3msbk	hfr stp	Few fine	Vertical cracks, many fine pores
	60-130	DS	7.5YR 4/1	2msbk	vhfrstp	Few fine	Few medium and coarse pores
	130-150+	DS	7.5YR 3/1	2msbk	vhfistkp	None	

[1]GS, Gradual and smooth; CS, Clear and smooth; CW, Clear and wavy; DS, diffused and smooth;

[2]Structure: 1, weak; 2, moderate; 3, strong; f, fine; m, medium; gr, granular; abk, angular block; sbk, subangular blocky;

[3]st, sticky; p, plastic; h, hard; fi, firm; cs, coarse; v, very; sl, slightly; fr, friable

Soil physical properties

Particle size distribution: The sand fraction of profile 4 is significantly ($p<0.05$) higher while, silt and clay contents are lower than the other profile soils (profile 1,2 and 3). In addition, the sand and clay fractions decreased and increased consistently with depth, respectively. On the other hand, the sand and clay fractions, respectively, decreased and increased with in profile depths of profile 1, 2, and 3. However, the relationship between the silt contents and soil profile depths in all sites were not consistent (Table 2). The ANOVA analysis presented in (Table 8) show that the soil textures were significantly ($P<0.05$) affected by both land use and profile depths whereas their interaction effect was not statistically significant.

Generally, there is a consistent trend of increasing clay contents and decreasing sand contents from the surface to the subsurface horizons for all profiles indicating that there was a translocation of clay down the profile and subsequent accumulation in the sub layers (Table 2). Similar findings were also reported by IUSS Working Group,[25] who noted that the textural differentiation within depth of soils might be caused by an illuvial accumulation of clay, selective surface erosion of clay, upward movement of coarser particles due to swelling and shrinking and a combination of two or more of these processes.

The relatively higher clay fraction in profile 1, 2 and 3 might be attributed to the fact that the area is located at the valley bottom position where further movement of runoff water ceases allowing its suspended clay particles to settle as time passes. Similar findings were reported by Abayneh,[33] in the soil of Raya valley who stated that the floods and the flood streams drop most of the coarser soil particles on the alluvial plains while mainly the fine suspended clay particles reach the valley bottoms. Generally the relative similarity of texture among these sites might be due to similarities in land surface configuration (Table 9).

Table 2 Selected physical properties of soils systems of Bisidimo

Profile	Depth (cm)	Particle size (%)				Textural class	Bd gcm^{-3}	Total Porosity (%)	Water content (v/v)		
		Horizon	sand	silt	clay				FC	PWP	AWHC
	0-30	Ap	37	25	38	CL	1.23	53.59	36.58	17.82	17.76
1	30-65	A1	35	24	41	CL	1.25	52.84	37.78	18.56	19.22
	65-100	A2	32	26	42	CL	1.28	51.70	39.72	19.24	20.16
	100-130	B	33	22	45	CL	1.31	50.57	41.25	20.32	20.93
	130-150+	B2	31	23	46	CL	1.32	50.19	42.71	21.14	21.57
		Mean	33.6	24	42.4		1.3	51.8	39.6	19.4	19.9
	0-20	Ap	32	29	39	CL	1.20	54.72	39.12	22.03	16.11
2	20-30	Bt1	29	25	46	CL	1.23	53.59	40.23	22.78	18.45
	35-90	Bt2	27	26	47	C	1.21	53.34	41.64	23.34	19.30
	90-150+	Bt3	25	25	50	C	1.18	55.47	42.88	23.56	19.32
		Mean	28.3	26.3	45.5		1.21	54.3	41.0	22.9	18.4
	0-15	AP	31	34	35	CL	1.19	55.09	38.23	18.3	19.32
	15.55	A1	26	36	37	CL	1.22	53.96	40.45	19.78	20.67
3	55.9	BSS1	22	28	50	C	1.25	52.83	41.52	20.21	21.31
	90-150+	BSS2	20	27	53	C	1.20	54.72	42.42	20.65	21.77
		Mean	24.8	31.3	43.8		1.2	52.9	40.7	22.0	20.8
	0-35	Ap	48	18	34	SC	1.25	52.83	32.45	19.41	13.04
	35.9	A1	40	22	38	SC	1.28	51.70	34.75	20.26	14.49
4	90-130	AB	36	28	36	SC	1.31	50.57	36.54	20.75	15.79
	130-160+	B	34	26	40	SC	1.33	49.81	37.63	21.21	16.42
		Mean	39.5	23.5	37.0		1.30	51.2	35.3	20.42	15.0

C, Clay; CL, Clay loam; SC, sandy clay; Bd, bulk density; FC, field capacity, PWP, permanent wilting point; AWHC, available water holding capacity

Bulk density and total porosity

The minimum (1.19gcm^{-3}) and maximum (1.25gcm^{-3}) surface layer bulk densities were recorded under profile 3 and 4, respectively (Table 2). The bulk density of soils in profile 1 and 4 generally showed increasing trend from the surface to the subsurface horizons while, profile 2 and 3 soils showed decreasing trend. This is not in agreement with the fact that bulk density generally decreased with an increase in clay content which has relatively higher total pore space.[34] The significant disparity in bulk density between sites could be ascribed to the significant difference in clay and soil OC contents of the sites (Table 2). This can be evidenced by the significant negative correlation of bulk density and soil OC of the area (Table 10).

The bulk densities of surface layers are generally lower than the subsurface layers was in agreement with the established fact that bulk density is lower at the surface due to relatively high organic matter content because of the decomposition of plant roots. However, Nega,[35] and Hartemink,[36] found an increasing trend of bulk density down the profile in shrinking and swelling dark clay soils. In line with this, Brady,[37] also pointed out that bulk density is generally higher in lower profile layers which results from a lower content of soil organic matter, less aggregation and root penetration, and compaction caused by the weight of the overlying layers.

As can be seen from (Table 2), the bulk density values of the surface soils were closer to the average bulk density (1.1-1.4gcm^{-3}) of cultivated loam soils.[34] Following the general relationship of soil bulk density to root growth, the root restricting bulk densities for clay is greater than 1.47gcm^{-3},[38] and for clay loam greater than 1.75gcm^{-3}.[39] Therefore, the bulk densities noted under all land uses may not limit root growth, air circulation and availability of less mobile essential plant nutrients. On other hand, the total porosity of the surface layer ranged from 53 to 55%. The values were within the range of total porosity (40 to 60%) of clay texture Michael and showed a decreasing trend with soil depth, however, it was maximum at the extreme bottom layers of profile 2 and 3. This could be related to the distribution of clay content and natural compaction of the subsurface soils by the load of surface soils.[40]

Soil water characteristics

The soil water characteristics presented in (Table 2) revealed that the lowest (32.45v/v) and the highest (42.88v/v) soil water content at field capacity (FC) were observed in the surface (0-30cm) and bottom layer (90-150^{+}cm) of profile 4 and 2, respectively. While, the lowest (17.82v/v) and the highest (23.56v/v) soil water contents at PWP were recorded in the surface (0-30cm) layers of profile 1 and the sub surface (90-150^{+}cm) layer of profile 2. The soil water contents at FC and PWP increased consistently with depth in all land uses which could be due to increased clay contents with profile depths. In line with the findings of this study, sub soil layers with high clay content in continuously cultivated farmers' field in Bako and Bisidimo also had the highest water content at FC.[8] Moreover, this is in agreement with the finding of Emerson,[41] who concluded that increasing in clay content increases both FC and the PWP.

As indicated in (Table 2), the available water holding capacity (AWHC) varied consistently within a profile and ranged from 13.04 to 21.57. The increasing trend of clay contents with depth have probably contributed to the consistency in available water holding capacity with depth. The values of AWHC of profile 1, 2 and 3 were slightly higher than the other profiles; this could be due to the increased retention of moisture with increasing clay contents at FC and PWP. Since available water holding capacity is a calculated value it followed similar trend to that of water content at FC and PWP. As it is presented in ANOVA (Table 3), significant (P<0.05) variation of PWP in between the land use types was recorded while, in case of FC and AWHC significant variations were observed in the interaction effects of land use and depth.

Table 3 Saturated hydraulic conductivity values of the soil measured using Gulf permeameter

Nearby profile	Coordinates		Ksat (cm hr^{-1})	Categories
	latitude	Longitude		
Profile 1	090 08' 761"	0420 15' 721"	0.16	Moderately slow
Profile 2	090 08' 789"	0420 15' 761"	0.11	Moderately slow
Profile 3	090 08' 859"	0420 15' 683"	0.13	Moderately slow
Profile 4	09008' 771"	0420 15' 533"	0.25	Moderately slow

Ksat, saturated hydraulic conductivity

Table 4 Soil organic carbon, total nitrogen and available phosphorous

Profiles	Depth	Soil OC (%)	Total N (%)	Ave. P(mg Kg^{-1})
	0-30	0.54	0.35	3.74
1	30-60	0.44	0.17	3.41
	6-100	1.05	0.14	2.40
	100-130	0.4	0.12	2.30
	130-150+	0.26	0.10	2.26
Mean		0.54	0.17	2.28
	0-20	0.25	0.13	9.81
2	20-35	0.19	0.12	9.32
	35-90	0.15	0.11	7.99
	90-155	0.13	0.09	6.62
Mean		0.18	0.11	8.44
	0-15	0.45	0.28	8.08
3	15-55	0.35	0.18	528
	55-90	0.16	0.11	5.23
	90-155+	0.14	0.11	3.08
	Mean	0.28	0.16	5.42
	0-15	0.45	0.28	8.09
4	15-45	0.48	0.22	8.40
	45-90	0.24	0.15	6.40
	90-150	0.25	0.12	6.32
	Mean	0.40	0.17	7.34

OC, Organic carbon; N, Nitrogen, Av.P, Available Phosphorous

Infiltration rates and saturated hydraulic conductivity

Infiltration rates of soils:

The soils of Bisidimo area showed slight variation basic infiltration and cumulative infiltration rates which could be due to slight differences in surface conditions such as surface cracks, clay content, surface crust and other factors.[42] The steady state infiltration and cumulative infiltration rates ranged from 2.2 to 3.0cm hr^{-1} and 22.6 to 29.7cm, respectively. As can be seen from (Figure 2), the soil in profile 4 show the highest infiltration rate at the beginning of the process and decreased steadily at different rates which could be

Citation: Adane A, Gebrekidan H, Kibret K. Assessment of the pysicochemical status soils and irrigation water qualities in eastern Ethiopia. *Forest Res Eng Int J.* 2019;3(3):91–104. DOI: 10.15406/freij.2019.03.00085

due to relatively higher sand and lower clay content relative to other profiles.[29] The other reason could be due to soil with high sand content has higher initial and steady infiltration rates than clay loam soils due to the fact that it has relatively coarse texture and large porous spaces which promote fast infiltration.[43] Moreover, the soils were saline and contained low exchangeable Na and clay content; which could not reduce the infiltratability of the soil due to swelling to minimize the porous space (Tables 2,5&6). Similarly, the soils in profiles 1, 2 and 3 (which have relatively higher clay content than profile 4) also showed higher infiltration rates at the beginning of the process and a decreasing trend with time. The reason could be due to the fact that the initial soil moisture was low due to dry soils in winter (*Bega*) when the experiments were conducted. Similar reports were released by Lili et al.[42] the lower the initial soil moisture content is, the higher the initial soil infiltration rate will be.

On the other hand, the relatively lower infiltration rates of soils in profile 2 and 3 could be due to higher exchangeable Na (ESP>15%) and clay contents (Tables 2,5&6) since clay particles may swell or disperse as they become wet and thereby reduced the size of the pores. The SAR values of profile 2 and 3 were also higher which could induce soil dispersion and structural deterioration leading to lower infiltration rates (Table 5). The study indicated that, the steady state infiltration rates were greater than the basic infiltration rates for clay loam soils (0.5-1.0cmhr^{-1}). However, Cuenca reported that infiltration rate varies greatly with soil structure and stability, even beyond the normal ranges. Thus, on the basis of basic infiltration rates established by Landon,[44] the soils in all profiles can be grouped into moderate, indicating that the soils of the area are suitable for irrigation with proper management.

Table 5 Soluble chemical composition of soils of Bisidimo, Babile District

Profile	Depth (cm)	pH	ECe dSm^{-1}	Na^+	K^+	Ca^{2+}	Mg^{2+}	SAR	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}
	0-30	7.7	5.22	13.88	2.67	5.96	2.64	6.69	0.29	nil	11.2	9.8
1	30-65	7.71	4.35	12.65	1.85	4.94	2.33	6.62	0.37		10.3	9.34
	65-100	7.88	3.42	11.78	1.31	4.84	1.75	6.49	0.48		10.06	9.22
	100-130	7.98	3.89	10.69	1.28	4.35	1.45	6.28	0.49		9.27	8.54
	130-150+	8.25	3.62	9.18	1.05	3.75	1.11	5.89	0.57		8.19	8.28
	Mean	7.9	4.1	11.64	1.63	4.77	1.86	6.39	0.44		9.8	9.16
2	0-20	8.47	4.46	25.45	1.09	5.72	1.48	13.41	0.86	nil	14.28	15.27
	20-35	8.51	4.66	25.96	1.22	5.81	1.27	13.8	1.02		15.09	15.58
	35-90	8.55	5.02	26.28	2.21	6.32	1.41	13.37	1.13		16.52	16.64
	90-150+	8.57	5.88	27.32	2.24	6.54	1.16	13.92	1.4		17.35	17.34
	Mean	8.52	4.51	26.25	1.69	6.1	1.33	13.62	1.08		16.27	15.96
	0- 15	8.35	4.68	29.29	1.26	5.04	1.16	16.64	1.35	nil	17.35	17.84
3	15- 55	8.48	4.72	29.82	1.35	6.38	1.35	15.17	1.42		16.79	18.35
	55- 90	8.51	4.85	30.43	1.68	6.49	1.54	15.19	1.47		16.15	19.84
	90-150+	8.54	5.48	31.79	1.98	7.76	1.98	14.41	1.53		15.45	20.73
	Mean	8.47	4.33	31.57	1.57	6.42	1.51	15.86	1.42		16.44	19.47
	0-35	7.76	5.12	12.96	2.31	4.37	1.32	7.68	0.4	nil	9.78	9.42
4	35-90	7.86	4.98	11.54	2.23	4.15	1.24	7.03	0.37		9.48	8.8
	90130	7.95	4.64	11.29	1.95	3.88	1.2	7.08	0.29		9.31	7.85
	30-160+	8.23	3.86	10.19	1.51	3.28	1.15	6.85	0.25		8.82	7.75
	Mean	7.89	4.65	11.75	2.24	4.31	1.25	7.05	0.33		9.34	8.92

ECe, electrical conductivity of saturated paste; SAR, sodium adsorption ratio

Table 6 Exchangeable cations and exchange properties

Profile	Depth (cm)	Exchangeable cations (cmol $_{(+)}$ kg^{-1})				CEC (cmol$_{(+)}$kg^{-1})	ESP (%)
		Na	K	Ca	Mg		
	0-30	5.56	1.64	24.9	6.16	38.22	14.55
1	30-65	4.85	1.36	23.5	6.12	35.87	13.52
	65-100	4.21	1.26	22.6	5.46	33.79	12.54
	100-130	3.83	1.17	22.3	5.43	32.75	11.70
	130-150+	3.43	1.04	21.5	4.74	30.66	11.19
	Mean	4.38	1.29	23	5.58	34.26	12.70

Citation: Adane A, Gebrekidan H, Kibret K. Assessment of the pysicochemical status soils and irrigation water qualities in eastern Ethiopia. *Forest Res Eng Int J.* 2019;3(3):91–104. DOI: 10.15406/freij.2019.03.00085

Table Continues...

Profile	Depth (cm)	Exchangeable cations (cmol $_{(+)}$ kg^{-1})				CEC (cmol$_{(+)}$kg^{-1})	ESP (%)
		Na	K	Ca	Mg		
2	0-20	8.67	1.35	26.2	6.28	42.52	20.39
	20-35	7.84	1.24	25.5	5.84	40.46	19.38
	35-90	7.01	1.12	24.1	4.84	37.09	18.9
	90-150+	6.52	1.23	23.3	4.14	35.29	18.48
	Mean	7.51	1.24	24.8	5.28	38.84	19.29
	0- 15	8.97	1.12	25.4	6.23	41.74.	21.49
3	15- 55	8.24	1.21	24.4	5.62	39.49	20.87
	55- 90	7.84	1.32	23.7	5.22	38.10	20.58
	90-150+	7.98	1.65	22.9	4.84	36.33	19.21
	Mean	8.01	1.33	24.1	5.48	38.92	20.54
	0-35	5.23	1.62	24.4	6.48	37.77	13.85
4	35-90	4.54	1.32	23.9	5.86	35.63	11.74
	90130	3.68	1.21	22.6	5.45	32.96	11.17
	30-160+	2.84	1.14	21.9	5.32	31.16	9.110
	Mean	4.07	1.32	23.2	5.78	34.38	11.71

CEC, Cation exchange capacity; ESP, Exchangeable sodium percentage

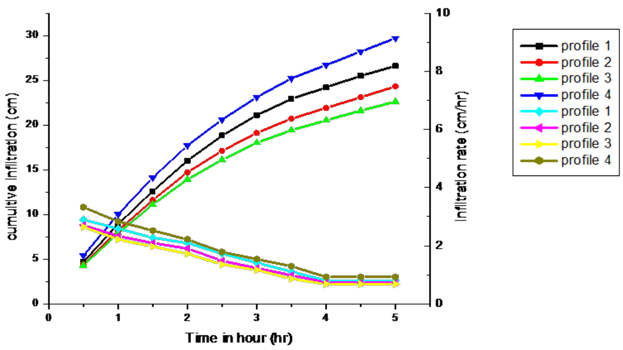

Figure 2 Cumulative infiltrations (cm) and Infiltration rates (cmha^{-1}) of soils against time.

Saturated hydraulic conductivity (Ksat) of soils:

The Ksat of the soils of the study area is presented in (Table 3). Results show that while the Ksat values in the study area were relatively similar, values in profile 4 were slightly larger than the other sites which could be to the fact that it (profile 4) had relatively higher sand content compared to other site soils. As a result, when saturated, the coarse textured soils have high Ksat than the finer textured soils.[45]

The relatively lower Ksat values of profile 2 and 3 could be due to high exchangeable Na, SAR and clay content in these soils could induce soil dispersion and structural deterioration (Table 2&5). The finding was also supported by Heluf,[13] who concluded that the most deleterious effect of high exchangeable Na and clay content in soils is the reduction in Ksat. Moreover, the similarity of Ksat values across the soils of profiles 1, 2 and 3 is expected, since the soils are relatively homogeneous with all surface layers being clay loam. Based on the basis of Ksat ratings established by Ghildyal and Tripathi,[46] the soil in all profiles can be grouped into moderately slow permeability class.

Chemical properties of soils of bisidimo, babile district

Soil organic carbon, total nitrogen and available phosphorus: The soil OC contents ranged from 0.25 to 0.54% in the surface horizon and 0.13 to 1.05% in the subsurface horizons could be categorized under low to medium level.[47] The values decreased inconsistently with increasing depth in profile 1 and 4 but decreased consistently in profile 2 and 3. The relatively higher soil OC content in the surface horizons could be ascribed to the presence of biomass for decomposition. On the other hand, the regular decrease of soil OC with depth could be due to decreasing root biomass with depth. The difference could be attributed to the rapid decomposition and mineralization of organic matter under cultivation practices.[48,49]

In line with the above clarification, the depletion of soil OC was relatively higher in cultivated lands (profile 2, 3 and 4) than the uncultivated land (profile 1). The reason could be due to the fact that cultivated lands are related to soil management practices that return little to no soil OC sources to the soil. In addition, a combination of lower OC inputs because of less biomass return on harvested land, increased aeration and removal of crop residue, the rapid turnover in the organic substrates derived from crop residue whenever added partly causes the reduction of soil OC in cultivated soils.[50]

The generally low soil OC contents in the present soils could be related to the complete removal of crop residues for different purposes and/or could be attributed to the warmer climate, which enhances rapid rate of mineralization,[40,51] and it is an indication of the absence of healthy soil biological conditions in the study area. Generally, the mean soil OC content of the different land uses in the study area were low. As per the rating of nutrients suggested by Tekalign,[47] the soil OC can be categorized as low and was significantly and positively correlated with total N ($P<0.001$, $r=0.434$), clay content and CEC values of the soil. Similarly, the total nitrogen (N) content of the profiles showed almost the same trend with soil OC contents. Total N contents ranged between 0.09 and 0.35% which is the range of low according to.[47,52] The soil in uncultivated land (profile 1) had relatively maximum mean total N (0.25%) while; cultivated lands had lower contents of total N (Table 4). The relatively lower TN contents in cultivated land uses (profiles 2, 3 and 4) might be due to the removal of the upper part of crop residues or lower addition of nitrogen containing inputs.

On the other hand, the minimum ($3.74mgkg^{-1}$) and maximum ($9.81mg\ kg^{-1}$) available phosphorous content of the surface soils were recorded in profile 1 and 2, respectively. The relatively higher Av.P observed in the cultivated lands (profiles 2, 3 and 4) than the non-cultivated land (profile 1) may be due to the different amount of external input applied on cultivated lands by farmers. As per the rating of nutrients suggested by Olsen et al,[21] the concentration of available phosphorous was medium under all soil management systems except the uncultivated land (profile 1) which is low in Av.P content.

Available phosphorous contents decreased consistently under all management systems from the surface to subsurface horizons (Table 4). The decrease with depth is attributed to the increment of clay content with depth and could be clay type which can cause fixation of P. This is in agreement with the findings of Tekalign et al.[53] and Asmare et al.[54] who reported that topsoil available P is usually greater than subsoil due to sorption of the added phosphorus, greater biological activity and accumulation of organic material on the surface. Generally, as it is presented in (Table 1), soil OC, total N and available P were observed to be affected significantly by depth and land use types ($P \leq 0.05$) whereas their interaction did not show any significant difference on these soil properties.

Soluble chemical compositions of the soils of bisidimo, babile district

Soil pH and electrical conductivity of saturated paste extract (ECe): The soil pH in profile 1 was slightly alkaline (pH: 7.70) in the surface and increased slightly with depth to moderately alkaline (pH: 8.25) in the extreme bottom layer. On the other hand, soils of profile 2 and 3 were alkaline (pH>8.35) throughout the entire depths of their respective layers and increased almost consistently with depth; this could be due to the dominance of Na^+ among the cations and the presence of sufficient amounts of HCO_3 ions among the anions. These results confirmed that the concentrations of exchangeable bases and HCO_3 ions are apparently the sources of slight variability of pH in the soils of the study areas.[5] Similarly, the pH of the surface soil opened at profile 4 was slightly alkaline (pH: 7.76) and increased almost consistently but slightly with depth to moderately alkaline (pH: 8.23) at the lower layer.

Generally, the mean pH of the soils ranged from 7.89 to 8.52 (Table 5) indicating that the soils are moderately alkaline in reaction.[55] considering the optimum pH for many plant species to be 5.5 to 6.8,[56] the pH of the soils in the study area could be considered as unsuitable for most crop production. The ANOVA analysis presented in (Table 10) show that the soil pH values had significant ($p<0.05$) and positive correlation with SAR, ESP, CEC and clay contents.

In line with the pH value, the ECe of profile 1 and 4 deceased inconsistently with depth from 5.22 to $3.62dSm^{-1}$ and from $5.12dS\ m^{-1}$ to $3.86dS\ m^{-1}$, respectively (Table 5). The inconsistent distribution of soluble salts within the profile could be due to the upward (capillary) movement of salts in saline ground water was more dominant than downward (leaching) movement of salts with rain waters.[8] Unlike profile 1 and 4, the ECe of profiles 2 and 3 increased consistently but gradually with depth from 4.46 to $5.88dS\ m^{-1}$ and from 4.68 to $5.48dS\ m^{-1}$, respectively (Table 5). The higher extent of salinity (ECe) at the underlying horizons than in the surface layers of these soil profiles revealed that the downward movement (leaching) of salt was dominant over that of the upward (capillary) movement of salt in areas having ground water containing higher dissolved salts. Similar results were observed by Heluf,[5] in Melka-Sedi Amibara, Fasika.[7] in Alage and Gizaw,[8] in Bisidimo in which relatively higher concentrations of soluble cations and anions, ECe and SAR at lower soil profile depths compared with their respective concentrations at and near the surface soil layers. This could be attributed to the dominance of downward leaching/ removal of soluble salts over surface accumulation of salts by upward movement of saline ground water. Generally, the mean ECe of all the profiles were greater than the salinity limit ($EC>4dSm^{-1}$) set by U.S. Salinity Laboratory Staff,[26] and Scianna et al.[57] to qualify for the saline soil class. The increasing concentration of soluble salts almost in all profiles revealed that the soils in Bisidimo area are being converted into a more saline phase calling for proper management in irrigating and drainage practices.

Soluble cations and anions in the soils of Bisidimo, Babile district

The data in (Table 5) shows that soluble Na^+ and Ca^{2+} are the dominant cations, whereas Cl^- and SO_4^{2-} are the dominant anions in all profiles. In agreement with the values of ECe, the decrease in these values with soil depth is apparent as the concentrations of all soluble cations and anions gradually decreased with depth almost linearly in profiles 1 and 4 (Table 5). Heluf,[5,8] also observed a relatively higher salt accumulation in the surface layers of some soils of the Melka-Sedi Amibara plain and Bisidimo area than at lower depths of the profile. They also described the situation as attributed to the dominance of capillary movement of salty ground water over leaching or removal of soluble salts to the lower horizons. Compared to profile 2 and 3, the concentrations of soluble cations and anions in profile 1 and 4 were generally low throughout the profiles and the lowest concentrations of the respective ions were recorded in the bottom layers.

Similarly, soluble Na^+ was the dominant cation followed by soluble Ca^{2+}, whereas soluble Mg^{2+} and K^+ were present in relatively lower concentrations in profiles 2 and 3 (Table 5). On the other hand, Cl^- and SO_4^{2-} were dominant anions throughout the soil layers of these profiles. The concentrations of soluble Na^+, Ca^{2+}, Cl^- and SO_4^{2-} increased linearly from the surface to the extreme bottom layer of profile 2 and 3. Higher extent of soluble salts at the underlying horizons than the surface layers revealed that the down ward movements (leaching) of the salts were dominant over that of the upward (capillary) movement of salt.[5,8] The relatively, higher concentrations of soluble Na^+ and Ca^{2+} among the cations, SO_4^{2-} and Cl^- among the anions present throughout the The sodium adsorption ratio (SAR) of the soil solutions ranged from 5.89 to 6.69 in profile 1, 13.41 to 13.92 in profile 2, 14.41 to 16.64 in profile 3 and 6.85 to 7.68 in profile 4 (Table 5). As per the ratings set by U.S .Salinity Laboratory Staff,[26] the SAR of the saturated paste extracts of the soils in profile 1 and 4 were medium but these values were higher for profile 2 and 3 throughout the horizons which may induce soil dispersion and structural deterioration leading to infiltration problems. According to the criteria set by the U.S. Salinity Laboratory Staff,[26] with regards to soluble salt content, regardless of their pH and ESP values, the soils of Bisidimo area represented by profile 1 and 4 are classified as saline soils whereas, soils in profile 2 and 3 are classified as saline sodic.

Exchangeable cations and exchange properties

The CEC of the soils of Bisidimo ranged from medium to very high as per the rating established by Hazelton and Murphy,[58] and decreased almost consistently from the surface to the subsurface horizons. The trends of the distribution showed similarity with the distribution of exchangeable Ca and Mg, since factors that affect these soil attributes also affect the CEC. The high CEC values (≥30cmol$_{(+)}$ kg^{-1}) in all profiles indicated the presence of more weather able primary minerals as a plant nutrient reserve and thus such soils are considered to be capable of satisfactory production if other factors are favorable.[12] Since CEC of soil is determined by the relative amounts and type of humus and clay content, it was closely and positively correlated with OC, TN and clay contents.

Some similarities observed in the distribution of exchangeable cations within the profiles of the different soil management systems. Accordingly, the abundance of the basic exchangeable cations showed consistent trends with increasing depths and were in the order of Ca>Mg>Na>K in profile 1 and 4, while the order reversed to Ca>Na>Mg>K in profile 2 and 3 (Table 6). The higher concentration of exchangeable Na next to exchangeable Ca in the latter two profiles could be due to continuous use of the irrigation water for crop production. The concentrations of exchangeable cations (Ca^{2+}, Mg^{2+} and Na^{+}) decreased linearly with increasing soil depth throughout all profiles. Exchangeable Ca^{2+} was found to predominate the exchange complex of the soil particles and its distribution was almost stable varying between 21.45 and 26.22cmol$_{(+)}$ kg^{-1}, however, accompanied by low concentration of soluble Ca^{2+} (Table 5&6). The comparatively higher exchangeable Ca content of these profiles supports the findings of Gizaw,[8] in the same area that Ca^{2+} is progressing in these soils.

The dominance of the exchangeable Ca in occupying the exchange sites of the soils could be confirmed by the fact that CEC had a significant and positive relationship with exchangeable Ca (r=0.960, P≤0.001) and exchangeable Mg (r=0.960, P≤0.001). Despite, Barber indicated that the critical level of exchangeable K for optimum crop production is 0.38cmol$_{(+)}$ kg^{-1}, exchangeable K in the area varied between 1.04 and 1.65cmol$_{(+)}$ kg^{-1}) but far lower than the other exchangeable cations. Soils in profile 2 and 3 contained higher exchangeable Na than soils in profile 1 and 4 compared to the critical level that brings deterioration of soil structure and Na toxicity.[25] The threshold level of exchangeable Na varied depending on the cation exchange capacity, clay content, clay mineralogy, and the type of crop grown.[51] Accordingly, the critical level is usually expressed in terms of ESP where on the average, an ESP of 15% is considered critical for most crops under most soil physical and mineralogical conditions.[26]

The mean ESP of soils demonstrated in (Table 6) varied from 11.19 to 21.34% and showed a declining trend with increasing soil depth following the same trend as distribution of exchangeable Na. The fact that the ESP and the concentrations of exchangeable cations are high at the surface horizons might be attributed to the capillary rise of the ground water during the dry season and its evapotranspiration loss leaving the salts contained in it on the surface horizon continually. Thus, soils near profile 2 and 3 had very high ESP (>15%) value to be classified as sodic/saline sodic, while soils under profile 1 and 4 had lower ESP (<15%) values to qualify for saline soil classification.[59–72]

Chemical composition of irrigation water of bisidimo

The chemical compositions of ground water taken from different locations were relatively close to each other (Table 7). The pH values of the ground water samples were relatively similar and ranged between 8.17 and 8.26 while, the mean pH value for Error River water was 8.18. The high pH values could be due to either the relatively higher value of HCO_3^- or the gaining of base forming ion or loss of neutral ions into the soil.[26] Similarly, the EC values of the ground waters ranged from 0.57 to 0.61dS m^{-1}, which was higher than the EC values of Error River (Table 7). Accordingly, the ground water samples met the total dissolved salt contents to be classified as having high salinity hazard based on the limits set by the U.S. Salinity Laboratory Staff.[26] On the other hand, the EC of the Errer River water was found to be 0.35dS m^{-1} and was relatively lower than that of the ground waters. Based on the widely used diagram for classification of irrigation waters by the U.S. Salinity Laboratory Staff,[26] the irrigation water source of Errer River can be classified under medium salinity hazard class; which implied that this water sample contained considerable concentration of dissolved salts which can gradually develop salt on soils upon continuous use for irrigation.

Based on the SAR vales, both water sources (the ground water and Errer River water) classified under the same class; low Na hazard class, regardless of their salinity hazard. Irrigation water with low Na hazard (SAR 0-10) can be used for irrigation on almost all soils with little danger of development of harmful levels of exchangeable Na content.[26] In general, with respect to most water quality parameters, both irrigation water sources in the study area contained medium to very high concentration of dissolved salts sufficient enough to gradually develop salt in soils upon continuous use for irrigation (Table 7). In line with the present study, Gizaw,[8] observed high to very high and medium to high dissolved salts in the ground and Errer River water samples, respectively, in the same study area.

On the other hand, both water sources contained various amounts of residual sodium carbonate (RSC) levels. Accordingly, the RSC contents of the Errer River was 1.78meq L^{-1} while, the ground waters in profile 1, 2 and 3 contained 2.88, 3.31 and 3.13meq L^{-1} RSC contents, respectively (Table 7). Thus, the RSC contents of Errer River was within the range of 1.25 to 2.50meq L^{-1} which is the range considered to be marginal to be used for irrigation purpose, however, the RSC contents of all the ground water sources were greater than 2.50meq L^{-1} to be classified as unsafe for irrigation purposes (Table 7) according to the classification limits set by the U.S. Salinity Laboratory Staff.[26]

Table 7 Chemical composition of water sample (mean values) of Bisidimo

		Characterization		Soluble cations (meqL^{-})				Soluble anions (meqL^{-1})					
Sample		**EC (dS m-1)**	**pH**	**Na^+**	**K^+**	**Ca^{2+}**	**Mg^{2+}**	**SAR**	**HCO_3^-**	**CO_3^{2-}**	**Cl^-**	**SO_4^{2-}**	**RSC**
Errer River water		**0.35**	**8.25**	**2.13**	**0.45**	**0.58**	**0.45**	**2.96**	**1.86**	**0.95**	**0.68**	**1.43**	**1.78**
Ground water	Profile 1	0.58	8.28	2.92	0.31	1.25	0.68	3.36	3.57	1.21	1.24	1.32	2.88
	Profile 2	0.57	8.3	3.53	0.60	1.06	0.35	2.99	3.41	1.31	1.11	1.78	3.31
	Profile 3	0.61	8.32	4.24	0.63	1.69	0.82	3.52	4.43	1.21	1.25	1.33	3.13
Mean		0.53	8.30	3.56	0.51	1.33	0.620	3.29	3.80	1.24	1.20	1.48	3.11

SAR, sodium adsorption ration; RSC, residual sodium carbonate; EC, electrical conductivity

Table 8 Mean square estimates of selected soil physicochemical properties

Soil properties	Land use			Depth			Depth* Land use			CV (%)	RMSE	R-square
	MS	F -Value	P -value	MS	F -value	P -value	MS	F -value	P -value			
sand	132.50*	13.75	<0.001	3.88 ns	0.4	0.8059	22.71ns	1.79	0.11	11.5	3.11	0.65
clay	260.16*	28.3	<0.001	88.95*	9.67	<0.001	31.48 ns	3.42	0.004	7.63	3.03	0.83
BD	33.46*	340.47	<0.001	16.10*	163.63	<0.001	2.01*	20.46	<0.001	2.7	0.03	0.59
FC	66.02*	0.19	<0.001	18.30 ns	0.19	0.9416	0.49 ns	0.01	1	29.71	9.8	0.07
PWP	37.54*	25.07	<0.001	7.06 ns	4.72	0.004	1.10 ns	0.73	0.678	5.91	1.22	0.75
AWHC	39.16	0.42	0.7405	2.70 ns	0.03	0.998	1.60 ns	0.02	1	78.9	9.67	0.04
pH	1.78*	53.78	<0.001	0.05 ns	1.52	0.22	0.04ns	1.07	0.41	2.23	0.18	0.86
ECe	5.69*	2476.97	<0.001	0.76*	330.99	<0.001	0.52*	226.83	<0.001	1.34	0.05	0.99
Na	5.01*	7591.63	<0.001	122.18*	33.88	<0.001	2.75*	18.55	<0.001	1.98	0.39	0.99
K	1.12*	682.34	<0.001	0.41*	248.17	<0.001	0.85*	518.43	<0.001	2.28	0.04	0.99
Ca	10.46*	349.46	<0.001	1.33*	44.34	<0.001	1.73*	57.91	<0.001	3.25	0.17	0.98
Mg	1.23 ns	7.13	0.008	0.58*	3.37	<0.001	0.58*	3.38	<0.001	26.84	0.42	0.64
SAR	260.84*	7598.64	<0.001	1.16*	33.89	<0.001	0.64*	18.59	<0.001	1.98	0.19	0.99
HCO3-	3.17*	530.93	<0.001	0.05*	5.86	<0.001	0.04*	1.39	<0.001	10.01	0.08	0.98
Cl-	167.01*	894	<0.001	19.13*	4.78	<0.001	0.76*	4.06	<0.001	3.42	0.43	0.99
SO22-	310.79*	2216.44	<0.001	3.29*	23.45	<0.001	2.74*	19.52	<0.001	2.88	0.38	0.99

MS, Mean square; CV, Coefficient of variation of treatments; *, significant at P≤0.001; ns, Non-significant at P<0.05; BD, Bulk density; FC, Field capacity; PWP, Permanent wilting point; AWHC, Available water holding capacity; SAR, Sodium adsorption ratio; RMSE, Root mean square error

Table 9 Mean square estimates for OC, TN, exchangeable cations (Na, K, Ca and Mg)

Mean squares					
Parameters	Treatment (47)	Error (47)	F value	Significant	CV (%)
OC	0.24 ns	0.23	0.0001	10.45	45.22
TN	0.01 ns	0.00	2.47	0.073	34.57
Av.N	82.32*	1.56	52.84	<0.001	21.47
Exchangeable cations					
Na	59.51*	0.58	101.93	<0.0001	12.52
K	0.01 ns	0.03	0.16	0.9231	13.08
Ca	4.00 ns	1.19	3.35	0.0267	4.55
Mg	0.43 ns	0.29	1.48	0.2322	9.67
CEC	74.55*	5.27	14.16	<0.001	6.22
ESP	283.46*	1.68	168.59	<0.001	7.99

Numbers in parentheses, degrees of freedom; CV, coefficient of variation of treatment; *significant at P≤0.001; CEC, cation exchange capacity; ESP, exchangeable sodium percentage

Conclusion

The soil morphological and physicochemical properties showed variations with land use types and soil depths indicated their variation in productive potential and management requirements for specific agricultural use. The particle size distributions of the soils are dominated by clay loam fractions. The infiltration rates and saturated hydraulic conductivity (Ksat) of the soils in all profiles were moderately slow. Exchangeable Ca was highly dominant throughout the exchange site of all profiles. With regard to the content of exchangeable Na, ESP, pH, ECe and SAR values, soils in profile 2 and 3 were classified as saline sodic while, soils in profile 1 and 4 were classified as saline.

The irrigation water sources contained from medium to high salinity hazard class and ranged from marginal to unsafe for irrigation. In general, the irrigation water sources contained medium to very high concentration of dissolved salts sufficient enough to accumulate salt upon continuous use for irrigation. Based on the findings of the study, it could be concluded that irrigation water could be the source for the development of saline sodic soils in the irrigated lands. Therefore, the resource poor farmers and stakeholders should implement low input management strategy to alleviate the problem of salinity/sodicity problems using cost effective and locally available amendments and selecting cultivars tolerant to salinity/sodicity levels either in combination or separately.

Funding

None.

Acknowledgment

This work was supported by a grant from the SIDA Project for which the authors are grateful. They also would like to acknowledge Hawassa College of Teacher Education and the SNNP Soil Laboratory Institute for providing the necessary resources to conduct the study.

Conflicts of interest

Authors declare that there is no conflict of interest.

References

1. Liang Y, Nikolic S, Peng M, et al. Organic manure stimulates biological activity and barley growth in soil subject to secondary salinization/ sodification. *Sols Biology and Biochemistry*. 2005;37(6):1185–1195.
2. Tajada M, C Garcia, J Gonzalea, et al. Use of organic amendments as a strategy for saline soil remediation: influence on the physical, chemical and biological properties of soil. *Journal of Soil biology and biochemistry.* 2006;38(6):1413–1421.
3. Qadir M, Oster J, Schubert S, et al. Remediation of sodic and saline sodic soil. A*dvances in Agronomy.* 2007;96:17–247.
4. Kidane Georgis, Abebe Fanta, Heluf Gebrekidan, et al. *Assessment of salt affected soils in Ethiopia and recommendations on management options for their sustainable utilization. A Task Force Report Submitted to the Office of the Deputy Prime Minister and Minister of Agriculture and Rural Development.* Ethiopia: EIAR, Addis Ababa; 2006.
5. Heluf Geberekidan. *Investigation on Salt Affected Soils and Irrigation Water Quality in Melka Sedi-Amibara Plain, Rift Valley Zone of Ethiopia.* MSc Thesis presented to the School of graduate Studies of Addis Ababa University; 1985.
6. Mesfin Mengistu. *Assessment of soils of irrigated lands and irrigation water quality in relation to soil salinity and sodicity in Meki-Zuwai area of Oromiya Region.* M.Sc. Thesis, Alemaya University; 2001.
7. Fasika Berhanu. *Characterization and Classification of Salt Affected Soils and Irrigation Water in Alage ATVET College Campus, Southern Rift Valley of Ethiopia.* MSc Thesis, Haramaya University; 2006.
8. Gizaw Berhanu. *Characterization and Classification of the Soils and Irrigation Water Sources of the Bisidimo areas. Babile District in East Hararghe Zone of Oromia National Regional State.* MSc Thesis, Haramaya University; 2008.
9. Achalu Chimdi, Heluf Gebrekidan, Kibebew Kibret, et al. Status of selected physicochemical properties of soils under different land use systems of Western Oromia, Ethiopia. *Journal of Biodiversity and Environmental Sciences.* 2012;2(3):57−71.
10. Abreha Kidanemariam, Heluf Gebrekidan, Tekalign Mamo, et al. Wheat crop response to liming materials and N and P fertilizers in acidic soils of Tsegede Highlands, Northern Ethiopia. *Agriculture, Forestry and Fisheries.* 2013;2:126−135.
11. Buol SW, Southard RJ, Graham RC, et al. *Soil Genesis and Classification. 5th ed.* Iowa State Press; 2003.
12. Abrol IP, Yadav JSP, Massoud FI. Salt affected soils and their management. FAO soils bulletin 39. 1988.
13. Heluf Gebrekidan. *Evaluation of the Potential Use of Langbeinite (K_2SO_4.2MgSO_4) as a Reclaiming Material for Sodic and Saline Sodic Soils.* A PhD Dissertation, Department of Soil, Water and Environmental Science, the University of Arizona; 1995.
14. Kalute A, Dirksen C. *Hydraulic conductivity and diffusivity: Methods of Soil Analysis, part1, 2nd ed.* Agron; 1986. p. 687–734.
15. MoARD. *Ethiopia: Building on Progress, A Plan for Accelerated and Sustained Development to End Poverty (PASDEP).* Addis Ababa: Ethiopia; 2006.
16. FAO. *Soil Map of the World, Revised Legend with Corrections. World soil resources report 60.* Italy: FAO; 1988.
17. FAO. Plant nutrition for food security: A guide for integrated nutrient management. Rome: Fertilizer and Plant Nutrition Bulletin 16; 2006.
18. Day PR. Hydrometer method of particle size analysis. In: CA Black, editor. *Methods of Soil Analysis. Agronomy Part I, No. 9.* USA: American Society of Agronomy, Madison, Wisconsin; 1965. p. 562−563.
19. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the titration method. *Soil Soc*. 1934;37(1):29−34.
20. Bremner JM. *Total Nitrogen. Methods of soil analysis. Part 3 Chemical methods.* USA: Soil Science Society of America Book Series, Madison; 1996;1065−1121.
21. Olsen SR, Cole V, Dean LA. Estimate of Available Phosphorous in Soil by Extraction with Sodium Bicarbonate. *USDA Cir. No.939*. 1954.
22. Hesse PR. *A Textbook of Soil Chemical Analysis*. John Murry Limited, London, Great Britain. 1971.
23. Okalebo JR, Gathua KW, Woomer PL. *Laboratory methods of soil and plant analyses: a working manual.* 2nd ed. TSBF-CIAT and SACRED Africa, Nairobi, Kenya. 2002.
24. FAO (Food and Agriculture Organization). *Physical and chemical methods of soil and plant analysis, FAO Soils Bulletin No. 10.* FAO of the United Nations, Rome. 1984.
25. International Union of Soil Science (IUSS). Working Group. World Reference base for Soil Resources: A framework for international classification, correlation and communication. 2nd Ed. *World Soil Resources Reports No. 103. FAO,* Rome; 2006.

26. United States Salinity Laboratory Staff. *Diagnosis and improvement of saline and alkali soils*. USDA Agri. Handbook. No. 60. U.S. Government Printing Office, Washington, D.C. 1954.

27. Reynolds WD, Elrick DE, Youngs EG. *Concentric ring infiltrometer*. In: Dane JH and Topp GC, editors. *Methods of Soil Analysis*. Part 4. Physical methods. SSSA. Book Ser. 5. *SSSA. Madison*. 2002.

28. SAS (Statistical Analysis System). SAS/STAT user's guide. Proprietary software version 9.00. *SAS Inst Inc Cary NC*. 2004.

29. Teshome Yitbarek, Heluf Gebere Kidan, Kibebew Kibret, et al. Soil survey, impacts of land use on selected soil properties and land sutabilty evaluation in Abobo area, Gambela Regional atate of Ethiopia. *A PhD Dissertation, School of Natural Resources and Environmental Science, Haramay University*. 2013.

30. Mishra BB, Heluf Gebrekidan, Kibebew Kibret. Soils of Ethiopia: Perceptions, Appraisal and Constraints in Relation to Food Security. *Journal of Food, Agriculture and Environment*. 2004;2:269-279.

31. Mohammed Assen L, Roux PAL, Barker CH, et al. Soils of Jelo micro-catchment in the Chercher highlands of eastern Ethiopia: I. Morphological and physicochemical properties. *Ethiopian Journal of Natural Resources*. 2005;7:55-81.

32. FAO (Food and Agriculture Organization). Lecture notes on the major soils of the world. *World soils resources report*. *No.94. Rome*. 2001.

33. Abayneh Esayas. Some physicochemical characteristics of the Raya Valley soils. *Ethiopian Journal of Natural Resources*. 2001;3:179-193.

34. Miller RW, Donahue RL. *Soil in Our Environment*. 7th ed. Prentice Hall. Englewood Cliffs, New Jersey. 1995.

35. Nega Emiru. Land Use Changes and Their Effects on Soil Physical and Chemical Properties in Senbat Subwatershed, Western Ethiopia. *MSc Thesis, Alemaya University*. 2006.

36. Hartemink AE. Sustainable land management at Ramu sugar plantation: assessment and requirements. *International Soil Reference and Information Centre, the Netherlands*. 1998;1-21.

37. Brady NC, Weil RR. *The Nature and Properties of Soils*. Pearson Education Ltd. Upper Saddle River, New Jersey. 2008.

38. United States Department of Agriculture (USDA). *Soil Quality Indicators*. USDA Natural Resources Conservation Service. Washington, D.C. 2008.

39. United States Department of Agriculture (USDA). *Soil Taxonomy*. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. 2nd Ed. Agriculture Handbook Natural Resources Conservation Service Number 436; 1999.

40. Abayneh Esayas. Characteristics, genesis and classification of reddish soils from Sidamo Ethiopia. *Doctoral dissertation, University Putra, Malaysia*. 2005;1-26.

41. Emerson WW. Water retention, organic carbon and soil texture. *Australian Journal of Soil Research*. 1995;33:241-251.

42. Lili M, Bralts VF, Yinghua P, et al. Methods for measuring soil infiltration: State of the art. *Interatoonal Journal of Agriculture and Biological Engenering*. 2008;1(1):22-30.

43. Iowa Storm water Management. *General information for infiltration practices*. 2008.

44. Jones JB. Agronomic Handbook: management of crops, soils, and their fertility. *CRC Press, Boca Raton, Florida, USA*. 2003.

45. Landon JR Booker. *Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics*. 1991.

46. Levy GJ, Goldstein D, Mamedov AI. Saturated Hydraulic Conductivity of Semiarid Soils: Combined Effects of Salinity, Sodicity, and Rate of Wetting. *Soil Science Society of America Journal*.2005;69:653–662.

47. Ghildyal B, Tripathi RP. Soil Physics. *Wiley Eastern Limited*. 1987;2,654–5.

48. Tekalign Taddesse. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No.13. *International Livestock Research Center for Africa Addis Ababa*. 1991.

49. Dengiz O, Info A. Morphology, physicochemical properties and classification of soils on terraces of the Tigris River in the South-east Anatolia Region of Turkey. *Journal of Agricultural Sciences*. 2010;16(3):205–212.

50. Wondwosen Tilahun, Sheleme Beyene. Identification of growth limiting nutrients in Alfisols : Soil physicochemical properties, nutrient concentration and biomass yields of maize. *American Journals of Plant Nutrition and Fertilization Technology*. 2011:1:23–35.

51. Assefa Adane, Teshome Yizengaw. Effects of Different Land Use and Management Practices on Soil Organic Carbon Stock in Butte Flecha (Shahmane District), Southern Rift Valley of Ethiopia. 2007.

52. Teshome Yitbarek, Heluf Gebere Kidan, Kibebew Kibret and Sheleme Beyene.2013. Soil survey, impacts of land use on selected soil properties and land sutabilty evaluation in Abobo area, Gambela Regional atate of Ethiopia. A PhD Dissertation, School of Natural Resources and Environmental Science, Haramay University

53. Havlin JL, Beaton JD, Tisdale SL, Nelson WL. *Soil Fertility and Fertilizer: Introduction to nutrient management*. 7th edition. Preason Education. 2005.

54. Tekalign Mamo, Haque I. Phosphorus status of some Ethiopian soils. *Plant and Soil*. 1987;102(2):261–266.

55. Asmare Melese, Heluf Gebrekidan. Phosphorous status, Adsorption Characterstics Kinetics Status and Availability to Wheat crop as Ifluenced by Application of Various Amendments on Acid soils of Farta District, Northenwestern High Lands of Ethiopia A. 2014.

56. Horneck DA, Sullivan DM, Owen JS, Hart JM. Soil Test Interpretation Guide. 2011.

57. Amacher MC, O'Neil KP, Perry, CH. Soil vital signs: A new Soil Quality Index (SQI) for assessing forest soil health. 2007.

58. Scianna J, Logar R, Pick, T. Testing and Interpreting Salt-affected Soil for Tree and Shrub Plantings. *Plant Materials Technical Note*. 2007.

59. Hazelton P, Murphy B. Interpreting Soil Test Results: What do all the numbers mean?. 2nd ed. PA Hazelton, BW Murphy, editors.CSIRO Publishing. 2007.

60. Bohn HL, McNeal BL, Connor GA. *Soil Chemistry*. 3rd ed. John Wiley and Sons, Inc. New York; 2001.

61. Eylachew Zewdie. Characterization and genesis showing andic properties. *Ethiopian Society of Soil Sci*. 2004;6(1):215–235.

62. FAO (Food and Agriculture Organization). Guidelines for soil profile description. 4th ed.FAO, Rome, Italy. 2006.

63. Geissen V, S*á*nchez-Hern*á*ndez R, Kampichler C, et al. Effects of land-use change on some properties of tropical soils: An example from Southeast Mexico. *Geoderma*. 2009;15:87–97.

64. Gupta GN, Prasad KG. Mohan S, et al. Salt affected soils: their management and reclamation for crop production. *Advance in Soil Science*. 1990;11:223–288.

65. Hillel D. Environmental Soil Physics. 1st ed. Academic Press. 2010.

66. Läuchli A. Epstein E. Plant response to salinity and sodic conditions. In: Tanji, KK, editors. *Agricultural Salinity Assessment and Management. American Society of Civil Engineers*. New York. 1990;71:113–137.

67. Murphy HF. A Report on the Fertility Status and Other Data on Some Soils of Ethiopia.1968

68. Mullins CE, Mackleod DD. Northcote KH, et al. Hardsetting soils. Behaviour, occurrence and management. *Advances in Soil Science*. 1990;11:37–108.

69. Munsell Colour Company. Munsell Soil Colour Company, Baltimor. 1975.

70. Rengasamy P. Transient salinity and subsoil constraints to dry land farming in Austrlian sodic soils: an overview. *Australian Journal of Experimental Agriculture*. 2002;42:351–31.

71. Soares JN, Espindola CR, Pereira WM. Physical properties of soils under soil acidity effects on nutrient use efficiency in exotic maize genotypes. *Plant and Soil*. 2005;192:9–13.

Citation: Adane A, Gebrekidan H, Kibret K. Assessment of the pysicochemical status soils and irrigation water qualities in eastern Ethiopia. *Forest Res Eng Int J*. 2019;3(3):91–104. DOI: 10.15406/freij.2019.03.00085