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Full Length Research Paper

Characterization and classification of salt affected soils and irrigation water in Tendaho sugarcane production farm, North-Eastern Rift Valley of Ethiopia

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Considerable area of land is becoming unproductive every year because of salinity and sodicity in lowlands of Ethiopia. For sound land use and irrigation water management, it is a paramount important to know the chemical composition of soils and irrigation water. Therefore, the study was aimed to evaluate the physicochemical properties of soils and irrigation water of Tendaho sugarcane production farm, located in north-eastern rift valley of Ethiopia. Depth wise soil samples from 4 different locations and 1 irrigation water sample from 2 sub-samples (from delivery head and the influent river) were collected. The result of the particle size analysis indicates that majority of the soils were heavily textured. The pH of the soil in all parts of the study area ranged from 7.8 to 8.6. Electrical conductivity readings of most of the studied soil profiles were high. Exchangeable sodium percentage values showed actual sodium toxicity problem (ESP>15) in the first profile and potential sodium toxicity (ESP>1) in the remaining profiles. On the other hand, the irrigation water has a low sodicity hazard; however, pH (7.65) and EC (0.654 dS/m) values clearly indicated that it is moderately alkaline and saline. Hence, coupled with water and soil analysis results, there will be a potential danger of sodicity and actual salinity development in the intended irrigation scheme. Thus, selection of crop type and proper irrigation methods should be designed for sustainability of soil productivity in the study area.

Key words: Salt affected soil, irrigation water, characterization and classification, sugarcane production.

INTRODUCTION

Ethiopia has great agricultural potential because of its vast areas of fertile land, diverse climate and large available labor pool (MoFED, 2010). However, agricultural production is very low because of various natural hazards and poor agricultural practices that have greatly reduced the productivity of soils. Soil is the basis of agriculture and natural plant communities (Udoh et al., 2016). Soil is at the root of food shortage, food insecurity or

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undernourishment which has assumed global dimension in the last three decades (Ogunkunle, 2015). In Rift Valley of Ethiopia, about 200 ha of irrigable land are dumped every year due to sodicity and associated land drainage problems (Heluf, 1987).

Debela (2017) explained that, soil salinity and alkalinity problems are particularly severe in developing countries, especially arid and semiarid regions, resulting in damage to the livelihoods of people in the short term, and with long term effects on food security of the country. Besides to these, heavy fertilizer application, use of poor quality irrigation water and inadequate drainage has contributed to rising groundwater tables leading to salinity-induced land degradation (Qureshi et al., 2013; Sarwar et al., 2015).

The rate of the occurrence of problematic soil in the Rift Valley areas of Ethiopian becomes particularly higher where water tables are near the soil surface with having high dissolved salts and irrigating without giving due consideration (Mesfin, 1998). As part of Rift Valley areas, Tendaho sugar cane production in Ethiopia could face salinity/sodicity problems unless proper land management activities are carried out based on the scientific data gained from land suitability evaluation (Janzen, 1988).

Seid and Genanew (2013) noted that, the existence of potential sodicity is not only in the soil but also in the irrigation water and their study underlines the need for selection of salt tolerant crops and good water management by using appropriate irrigation methods to sustain productivity. This has significant contribution to deciding the type of crop to be produced and appropriate irrigation methods for sustainability of soil productivity. For appropriate land use and water management in irrigated area, knowledge of the chemical composition of the soil characteristics, water, drainage condition and irrigation methods should be evaluated before implementation of irrigation projects (Seid and Genanew, 2013).

This calls for special attention for their proper management to ensure sustainable agricultural productivity and environmental quality. The indiscriminate land use practices in Dupti Tendaho Sugarcane production factory, Northeastern Ethiopia, have given rise to serious ecological problems and loss of land resources. Efforts to address these problems are highly essential, particularly in generating the needed information necessary for proper land use planning to guarantee sustainable agricultural development and environmental quality. Owing to the aforementioned facts, this study was undertaken to characterize and classify the soils and irrigation water in Tendaho sugarcane production farm.

MATERIALS AND METHODS

Description of the study area

The study was conducted at Tendaho irrigation project (Dupti plantation) which is found at Dubti Woreda, Afar regional state. It is situated at a longitude of about 40°57'486''E and a latitude of 11°40'786''N. The study area is located at about 590 km North East of Addis Ababa, capital city of Ethiopia. The farm occupies a total area of 6,500 ha, which is topographically gentle/flat surface. It is situated at Latitude and Longitude of 11° 41’ 20’’ N to 11° 48’ 40’’ N and 41° 6’ 0 ‘’E to 41° 41’30’’E, respectively and at an altitude of 402 masl. (Figure 1). Mean monthly rainfall ranges from 3.9 to 57.7 mm per year, average annual minimum and maximum temperatures are 20.2 and 37.1°C, respectively. Sugar cane is being cultivated in Tendaho farm by using furrow irrigation system from Awash River.

Sampling site selection, and soil and water sampling

Sampling site selection

Prior to the opening of soil profiles, personal field observation of the area within the valley was carried out to determine which specific areas should be selected as representative sites of the study area on the basis of land use. The sampling site section was done on the bases of irrigation history of irrigated lands.

Accordingly, four representative soil profiles study sites were selected which are representing different cultivation histories. Profile 1 is located at the most low-lying portion of the farm. This area of farm has long been irrigated for cotton production; and is fundamentally a challenging farm site to manage it under the ordinary farm management practices and repetitive crop failure has been occurred. Profile 2 represents, non-irrigated shrub field (the area currently not being used for production).

Irrigated matured sugarcane production farm (Profile 3) represents the land area which has been used to grow sugarcane for more than 4 years. Finally, Profile 4 represents the fallow land with no production (no any plant). In addition, four composite surface soil samples (0 to 30 cm depth) were collected from the farm lands represented by the four different soil profiles. Each composite surface soil sample was collected from a plot size of 25 m by 25 m from the land area represented by the respective soil profile. Accordingly, each composite surface soil sample was made from 16 (4 x4) randomly collected sub-samples of 0 to 30 cm depth. The randomly collected sub-samples were bulked to form composite samples.

Soil profile sampling

After site selection, representative soil profiles were opened. Accordingly, one fresh profile (1.20 m wide, 2.00 m long and 1.06 to 2.00 m deep) was opened on each representative site and soil samples were collected from each depth of the profiles. The soil profiles opened on each site were described for their morphological properties in the field and soil samples were collected depth wise from each genetic horizon or soil layer for characterization of their physicochemical properties in laboratory. Profiles were all divided into soil layers according to the evidence of pedogenic horizon development when applicable and to sampling layers where genetic horizons were not evident. Sampling and description of the layers were made according to FAO (2006) guidelines for soil profile and site descriptions, and soil color was interpreted using the Munsell Color Chart.

Laboratory analysis of soil samples

The soil samples was air-dried, ground and sieved through a 2 mm (10 meshes) size sieve and through a 0.5 mm (40 meshes) size sieve for parameter requiring such fine soil particles. Particle size

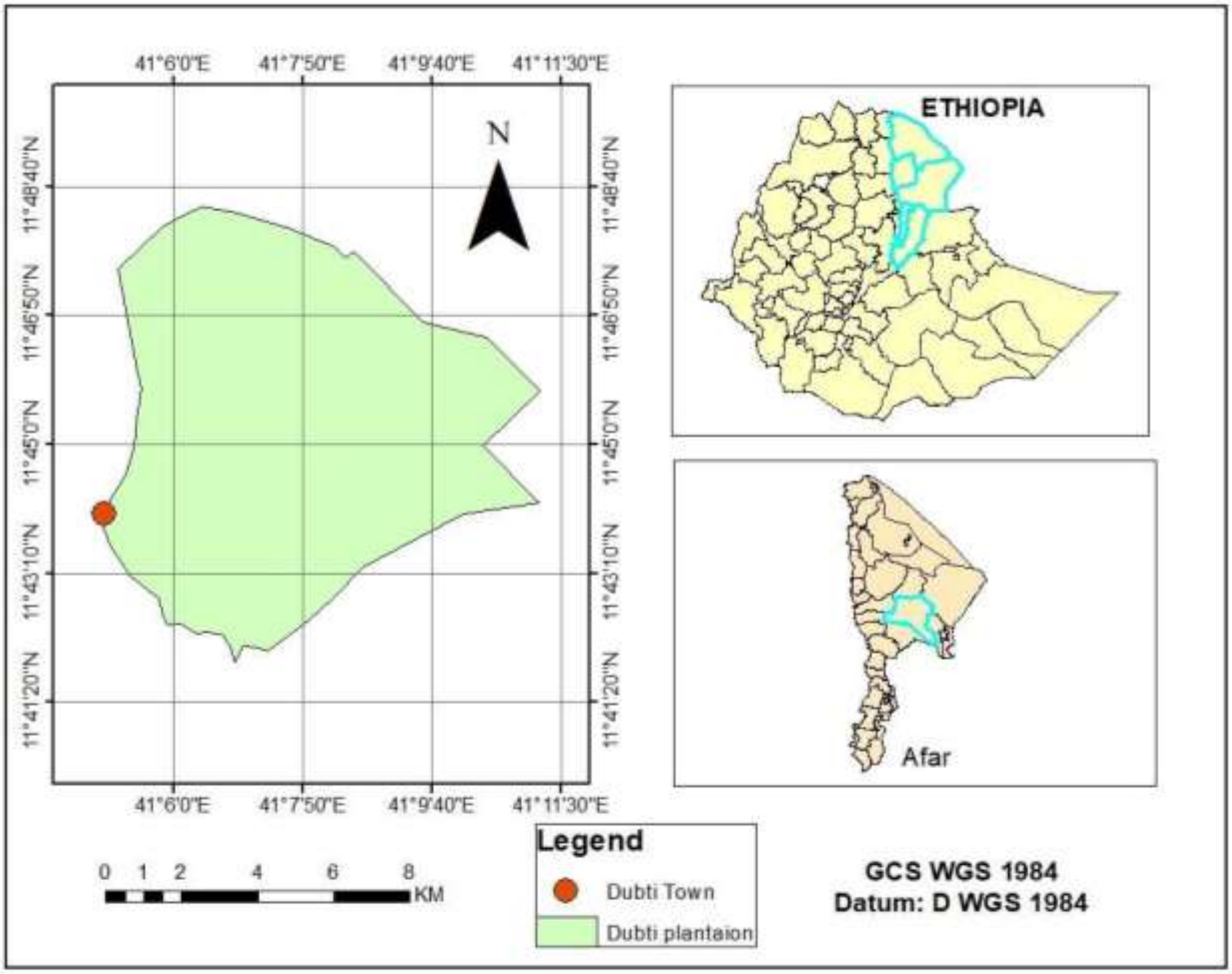

Figure 1. Location map of the study area

distribution was determined by Bouyoucos hydrometer method. Soil pH was read by pH meter in a soil: liquid ratio of 1:2.5. EC measurement was performed using saturated paste extracts. Total nitrogen of the soil was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Organic carbon was determined by the wet combustion method of (Walkley and Black, 1934). Available phosphorus was determined by the Olsen method (Olsen et al., 1954) as outlined by FAO (2002). Exchangeable bases and cation exchange capacity (CEC) of the soils were determined by ammonium acetate of 1 M leaching at pH 7 while calcium carbonate ($CaCO_3$) was determined by acid neutralization (titration) method using HCl (Van Reeuwijk, 1993).

Water quality analysis

A water sample was prepared from sub-samples collected at two sites, that is the irrigation delivery head site and the influent river (inlet to) the dam and at five different time intervals so that representative water samples could be obtained. The irrigation water samples from the dam were collected in one day. The collection and handling of the irrigation water samples was done in accordance with the procedures outlined by the US Soil Salinity Laboratory Staff (1954). Based on this principle one liter water sample was taken from Awash River for analysis of pH, EC, Ca, Mg, Na, Cl, K and SAR. Sodium adsorption ratios (SAR) of the soil solution and irrigation water samples were computed as:

$$SAR = Na^{+}/[(Ca^{2+} + Mg^{2+})/2]1/2$$

Where concentrations of all constituents are given in meq/l

Data analysis

The data generated from laboratory analyzed descriptive statistics. One way analysis of variance was used to compare the physical and chemical properties of soil between and within soil mapping units. All the data were edited, coded and analyzed using statistical package for social science (SPSS) software version 22.0.

RESULT AND DISCUSSION

For characterizing the physico-chemical properties of soils, the sampling site section was done on the bases of uniformity of land attributes. Accordingly, the catchment had four representative soil profiles study sites which are representing different cultivation histories of the area.

Table 1. Physical characteristics of the studied soils in four sites.

Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Soil textural class
Profile 1				
0-30	52	30	18	Clay
30-80	28	58	14	Silt clay loam
80-167	18	54	28	Silt loam
Profile 2				
0-31	38	40	22	Clay Loam
31-87	28	58	14	Silt clay loam
87-122	18	50	32	Loam
Profile 3				
0-28	38	40	22	Clay Loam
28-83	32	54	14	Silt clay loam
83-160	28	46	26	Clay loam
Profile 4				
0-32	42	30	28	Clay
32-81	32	52	16	Silt clay loam
81-160	16	54	30	Silt loam

Soil physical properties

In the soil profile description, the horizon boundaries of the pedons were marked by clear to gradual and smooth boundary characteristics. The surface horizons of these pedons had clear and smooth boundaries and the subsurface horizons had diffused to gradual and smooth boundaries. It is an indicator of a more or less uniform development of the horizons of the profiles. Depth of all the representative pedons was ranged from 122 to 167 cm. All sampled pedon representing different land use were found to be deep in depth with layers indicating limited soil profile development and dominated by silt loam and silt clay loam. The results revealed that the surface soils of Profiles 1, 2, 3 and 4 have the color of were light gray, dark gray, brown and gray in colour (dry) and grayish brown, dark grayish brown, brown and dark gray (moist), respectively.

The mean clay content of the surface layers varied from 38 % for Pedon 2 soils to 52% for pedon 1 soils. Also, except for Pedon 2, the clay content of all Pedon decreased with depth. The mean silt content varied from 30% at the surface layer (0-30cm depth) of Pedon 1 and 4 soils to 58% at the subsurface layer (31-87cm depth) of Pedon 2 soil. In the subsurface layer (30-87 cm depth), it varied from 52% to 58%. The silt content of Pedon 4 increased with depth where as other Pedon was consistent.

In this study, the lowest sand content (14%) was recorded in the subsurface layers (28 to 87 cm depth) of pedon 1, 2 and 3 soil and highest (32%) mean sand contents was recorded subsurface of surface layer (0-31cm depth) of Pedon 2. This relatively lower content of sand at the subsurface layers may indicate eluviation of clay and silt from the overlying layers and subsequent accumulation in the subsurface layers. The significant variations in respective particle size distribution observed in the different soil layers indicate the presence of distinct lithological discontinuity within the soil profile. Generally, results of the particle size analysis indicate that the majority of the soils are heavily textured. These properties may have an impact on movement of air and water within the soil (Brady and Weil, 2002).

Such abrupt changes in the distributions of the sand and silt fractions with corresponding changes in the clay contents with soil profile depths indicate the occurrence of erosion and sedimentation processes, resulting in deposition of sediments differing in particles sizes and/or parent materials in the area. Similar findings were reported by Abayneh (2001) in connection to his study of the soils of Raya Valley, Ethiopia. Moreover, Heluf (1985) observed evidences for the presence of litho-logical discontinuities or variability in mineralogy indicating a difference from which the horizons have been formed in the soils of Melka Sedi-Amibara plains (Table 1).

Soil chemical properties

Soil reaction and electrical conductivity

The pH values of surface soil horizons of the studied pedons varied from 7.8 to 8.6, which can be described as moderately alkaline and strongly alkaline as suggested by Park et al. (2011). In pedon1, the pH values dicreased from 8.4 (in surface horizon) to 8.2 (in sub-surface horizon), and it comes back again to 8.6 in last sub-surface horizon Pedons 2 and 3 also showed similar pattern, it was 8.3 and 8.2 in the surface horizons; decreased to 8.0 and 7.9 and it come back again to 8.4 and 8.5 in the last sub-surface horizon, respectively. In contrast, in pedon 4, the pH was increased from 7.9 in the surface horizon to 8.3 and come back again to 7.8 in the last subsurface horizon (Table 2). The rise in pH was attributed to the highest concentration of HCO_3- and the subsequent results of Residual Sodium Carbonate (Seid and Genanew, 2013).

Electrical conductivity of the first site ranges from non saline (0.97 ds/m) for the surface layer and to moderately saline 7.5 ds/m for the next subsurface layer. Whereas EC of the second site was non-saline that ranges between 0.459 dS/m on the surface soil (0 to 31) to 0.83 dS/m in the sub soils of the lower layers (31 to 155 cm) soil depth (Table 2). In site three, all the layers were found to be moderately saline with the EC of 7.455 from the top layer and (6.9 and 5.085) in the consecutive sub surface horizons. On the other hand, the result of EC in pedon four showed that it is non saline 1.68 ds/m for the first layer of the profile but moderately saline (4.635 to 7.29) for the consecutive subsurface horizons.

Indeed, in most of the studied profiles, electrical conductivity (EC) of the soils was higher than 4 dS/m, indicating that there would be actual salinity hazard in the soils of the study area (US Salinity Laboratory Staff, 1954). On the other hand, in all profiles except profile 3, the electrical conductivity was increasing from horizon 1 to 2 while decreasing from horizon 2 to 3; this could be due to the fact that soil salt may be leached out from the surface to sub-surface horizons. (Lelago et al., 2016)

Cation exchange capacity (CEC)

The result revealed that, in all of the opened profiles excavated on different land uses, medium to higher values of CEC were observed both in the surface horizons and the underlying horizons (Table 2). In the surface horizons, values of CEC varied from 27.38 cmol (+)/kg soil in profile opened on irrigated land used to grow sugarcane (Profile 3) to 64.42 cmolc kg-1 soils on non-irrigated shrub field (Profile 2). In the subsurface horizons, the CEC values varied from 26.20 cmol (+)/kg soil on site which has long been irrigated for cotton production (Profile 1) to 49.38 cmol (+)/kg soil in profile opened fallow land (Profile 4). The CEC of the soils in both surface and sub-surface layers ranged was high to very high as per rating set by Lelago et al. (2016). This indicates that, the soils have well in buffering capacity to changes in chemical properties caused by land use system (Hazelton and Murphy, 2007). The high to very high CEC values in the soils of the study area indicates the presence of more weather able primary minerals as a plant nutrient reserve and thus such soils are considered to be soils capable of satisfactory production if other factors are favourable (Lelago et al., 2016).

Soil organic matter and total nitrogen

Organic carbon of all horizons varied from 0.164 - 0.753% (Table 2), which can be described as very low ($\leq$ 2%) according to Tahere et al. (2005) rating. This could be due to the fact that the arid areas have relatively lower amount of OM because of lower vegetation and is an indication of absence of healthy soil biological conditions in the study area (Seid and Genanew, 2013). In addition, Yihenew (2002) revealed that most cultivated soils of Ethiopia are poor in their organic matter content due to low amount of organic materials applied to the soil and complete removal of the biomass from the field.

According to the ratings given in Tahere et al. (2005), total nitrogen content of all profiles (ranging 0.019 to 0.061%) of the study area is very low ($\leq$ 0.1). Similar to contents of organic carbon, amount of total nitrogen in subsurface horizon of all pedon generally showed relatively higher than other upper and bottom horizons. Thus, variation in total nitrogen content is related to variation in content of organic carbon. The lowest level of total nitrogen content indicates the presence of nitrogen deficiency in most of the soils of the study area. The low levels of nitrogen in the soils could be attributed to the poor farming system prevailing in the area, which is characterized by nutrient mining in the absence of replacing crop nutrients through addition of legume crop residues and manures and crop rotation (Brady and Weil, 2002).

Available phosphorus and calcium carbonate

Based on the observed values of available phosphorus, the soils represented by profile 1 had medium (13.53) available P values at the surface horizon and low (5.73 and 5.57) at the consecutive bottom layers of the profile with a decreasing trend of P down the profile. On the other hand, in site two and three the profiles have lower contents of available phosphorus (6.87 and 7.26) for surface soils and 12.40 and 11.09 (medium) for the next subsurface layer and decreased to 6.25 and 5.07 for the last subsurface soil horizon, respectively (Table 2). In the last site (profile 4), there was decreasing trend of available P down the profile; from medium (10.178) for surface to low (8.13 to 4.96) for the consecutive subsurface layers.

For all of the pedon, contents of calcium carbonate showed an increasing pattern with depth (Table 2). Contents of $CaCO_3$ ranged from 3.20% in the last subsurface horizon of pedon 2 to 11.49% in the last subsurface horizon of pedon 3. On the other hand, in all pedons except the first pedon the last subsurface horizon showed relatively higher levels of calcium carbonate than surface layers. Thus, this situation could be attributed to the movement of calcium carbonate solutes laterally downward to the lowest slope position. Generally, the

Table 2. Chemical composition of soils at four sites across soil depth.

Depth (cm)	pH (H_2O)	EC ds/m	TN %	OC %	OM %	Available P (mg kg^{-1})	CEC (cmol (+)/kg)	K (cmol (+)/kg)	Na (cmol (+)/kg)	ESP (%)	$CaCO_3$ (%)	Ca (cmol (+)/kg)	Mg (cmol (+)/kg)	Base Sat. (%)
Profile 1														
0-30	8.4	0.97	0.058	0.276	0.47	13.53	48.66	0.91	2.4	4.93	5.37	22.34	7.46	90
30-80	8.2	7.5	0.025	0.164	0.28	5.73	32.10	1.02	9.3	28.96	6.62	41.23	2.59	97
80-167	8.6	2.57	0.020	0.252	0.43	5.57	26.20	0.96	3.175	12.06	5.61	29.24	1.23	81
Profile 2														
0-31	8.3	0.459	0.061	0.734	1.26	6.87	64.42	0.87	1.89	2.93	3.20	34.58	1.48	88
31-87	8.0	0.83	0.032	0.464	0.79	12.40	43.60	1.11	4.5	10.32	4.63	31.35	1.77	84
87-155	8.4	0.489	0.019	0.351	0.60	6.25	32.10	0.91	3.625	11.27	8.49	27.92	1.32	83
Profile 3														
0-28	8.2	7.455	0.056	0.753	1.29	7.26	27.38	1.08	1.56	5.69	7.23	35.94	1.40	82
28-83	7.9	6.9	0.037	0.429	0.74	11.09	47.50	0.91	5.3	11.15	4.67	27.25	1.19	67
83-160	8.5	5.085	0.031	0.480	0.82	5.07	37.12	0.99	2.125	5.71	11.49	29.15	1.36	83
Profile 4														
0-32	7.9	1.68	0.059	0.206	0.35	10.17	61.48	1.04	0.78	1.27	3.25	42.94	2.80	95
32-81	8.3	7.29	0.036	0.229	0.39	8.13	49.38	1.04	2.5	5.06	7.54	30.48	1.77	73
81-160	7.8	4.635	0.022	0.238	0.41	4.96	37.24	0.84	1.92	5.15	11.27	26.66	1.40	84

result revealed that all layers of the profiles are found to be more that 2%; which resulted in the presence of a calcaric soil material (Hazelton and Murphy, 2007) (Table 2).

Exchangeable cations and percentage base saturation (PBS)

The predominant soluble cation was Ca^{2+} throughout the profile, followed by Mg^{2+} at the surface layer of profile 1 (0-30 cm) and 4 (0-32 cm) and Na^{+} at all the rest layers of the profile. The order of abundance of the basic exchangeable cations was Ca > Mg > Na > K in pedon 1 and 4 of surface and Ca > Na > Mg > K in the rest all horizons of pedons (Table 2). In line with the explanation given by Heluf (1985), the lower of amount of CO3 $^{2-}$ throughout the profile seemed to have favored the adsorption of the divalent cations by the soil exchange site to a significant extent. In addition, the CEC of the study area varies between 27.38 and 64.42 cmol (+) kg^{-1} soil on the surface layers, while it ranges from 26.20 to 49.38 cmol (+) kg^{-1} on the sub surface soils. This indicates the high availability of cation saturation in the study site. Similar findings were also reported by Eylachew (2004) on soils of the Rift Valley System of Ethiopia showing andic properties.

Furthermore, the explanation given by Abejehu (1993) also reported the dominance of exchangeable Ca throughout the depths in soils of the Metehara State Farm of the Middle Awash Valley of the Ethiopian Rift System. Similar findings were also explained by Fasika (2006) on soils of the Alage ATVET College Campus of the Ethiopian Rift Valley.

Percent base saturation (PBS) values are used as indicator of soil fertility status. In general, the soils of the study area had high base status values, containing over 70% (Table 2) and thus indicating the presence of hypereutric base status. The high PBS values in all the horizons also indicate the existence of low leaching processes in the horizons which might be due to the influences of poor drainage conditions of the profiles as well as the presence of appreciable

Table 3. Physico-chemical properties of soils at three four (mapping units) (Mean + SE).

Soil parameter	Mapping unit\Level of significance						
	Site One	Site Two	Site Three	Site Four	F-value	p-value	Rating
pH	8.400±0.2	8.23±0.21	8.2±0.3	8.0±0.26	1.329	0.331	High
EC (dS/m)	3.68±3.40	0.593±0.21	6.48±1.22	4.535±2.81	3.426	0.073	Low to medium
TN (%)	0.03±0.02	0.04±0.02	0.04±0.013	0.039±0.018	0.074	0.972	Low
OC (%)	0.22±0.059[b]	0.5±0.19[a]	0.55±0.17[a]	0.22±0.02[b]	5.308	0.026	Low
OM (%)	0.39±0.10[b]	0.88±0.33[a]	0.94±0.30[a]	0.38±0.030[b]	5.205	0.028	Low
Avail. P (ppm)	8.27±4.55	8.50±3.38	7.80±3.04	7.75±2.62	0.033	0.991	Low to medium
CEC(cmol (+)/kg)	35.65±11.64	46.70±16.38	37.33±10.06	49.36±12.12	0.84	0.50	High
K	0.96±0.055	0.96±0.12	0.99±0.08	0.97±0.11	0.060	0.980	High
Na	4.95±3.77	3.33±1.32	2.99±2.02	1.73±0.87	1.014	0.436	Medium to high
ESP	15.31±12.34	8.17±4.56	7.51±3.14	3.82±2.21	1.473	.293	Low to medium
$CaCO_3$	5.86±0.66	5.44±2.73	7.79±3.44	7.35±4.01	0.433	0.736	-
BS	89.33±8.02	85.00±2.64	77.33±8.96	84.00±11.0	1.084	0.410	-

Similar letters or no letters with rows indicate that there is no significant difference among parameters, α = 0.05.

amounts of base nutrients in the soils (Sunitha et al., 2010) (Table 3).

The level of exchangeable sodium percentage of the profile opened at the most low-lying portion of the farm varied from 4.93 at the surface (0 to 30) to 28.96 at the depth of 30 to 80 cm. According to Horneck et al. (2007), soils with >15 ESP have a high sodicity risk due to the effects of Na on soil structure and toxicity to crops. Accordingly, the soils represented by this profile were characterized by sodicity hazards. On the other hand, the other profiles of the study area aranges from 1.27% at the surface soil (0 to 32 cm) of profile 4 to 11.27% at the last subsurface (87 to 155 cm) of profile 2. These ESP values show that there is sodium toxicity problem in the first study sites to reduce the sugarcane crop yield and other study sites are no actually sodic. In general, soils with exchangeable Na >1 cmol (+)/kg should be regarded as potentially sodic (Brady and Weil, 2002). This indicates that the soils of other profiles are also potentially sodic.

Soil chemical characters among mapping units

The ANOVA results indicated that there were significant variations for OC and OM among the four mapping units (profiles). Accordingly, significantly higher (P<0.05) OC (0.5±0.19 and 0.55±0.17) and OM (0.88±0.33 and 0.94±0.30) were recorded on profile two and three.

However, soil pH, EC, TN, available phosphorus, CEC, K, Na, ESP, $CaCO_3$ and base saturation were not significant different among the four sites with different land use. On the other hand, except some soil properties (pH, CEC, K, Na), most of them are available in low amount according to FAO guideline (Table 3).

Irrigation water quality

Irrigation water quality was analyzed for SAR, pH, EC and other parameters of the water. The amount of sodium in irrigation water is of special concern due to sodium effects on the soil and poses a sodium hazard usually expressed in terms of SAR. SAR is calculated from the ratio of sodium to calcium and magnesium as they tend to counter effects of sodium. The SAR value of Awash River was found to be 1.17 (Table 4). Thus, the irrigation water in use had a low sodicity hazard. Similar findings were also reported for the Awash River water at the Matahara Sugar State Farm (Abejehu, 1993; Alamirew, 2002) in the Middle Awash Valley Ethiopia.

The average pH value of the irrigation water for Awash River at the delivery head site and the influent river is 7.65 (Table 4). On the other hand, the EC of the irrigation water was 0.654 dS m^{-1}. These pH and EC values clearly indicated that the irrigation water was moderately alkaline with the salt content classified as moderately saline (0.654 EC (dS/m) (Table 4) as outlined by different researchers (Biswas, 1998; Ayers and Westcott, 1985). The dominant ions in the irrigation water samples were dissolved HCO_{3-} and Ca^{2+}, followed by Na+. This indicated that bicarbonates of calcium and sodium ions were the dominant salts in the irrigation water which was in agreement with the findings of Alamirew (2002) on the Awash River.

Indeed, the water sample revealed that the irrigation water was medium in soluble salt concentration (salinity hazard), low in sodicity hazard and safe in residual sodium carbonate hazard (US Salinity Laboratory Staff, 1954) (Table 4).

Conclusion

Effective control of soil salinity requires better understanding on the extent and distribution of salts. This work focused on the recognition of the problem, by characterizing the physicochemical properties of the soils

Table 4. Chemical composition of water used for irrigation of the two sites.

Water parameters	Units	Degree of Restriction (Biswas, 1998; FAO, 1985b soil Bulletin 55; Ayers and Wesstcott,1985)			Values for Awash river	Severity status
		None	Slight to moderate	Severe		
Electrical Conductivity(EC)	ds/m	<0.70	0.70-3.00	>3.00	0.654	Slight to moderate
Sodium (Na^+)	meq/l				1.05	Normal
SAR	$meql^{-1/2}$	<3.00	3.00-9.00	>9.00	1.17	Low
Calcium (Ca^{2+})	meq/l	0 – 800: normal range		-	1.25	Normal
Magnesium (Mg^{2+})	meq/L	0 – 120: normal range		-	0.4	Normal
Potassium (K^+)	-	-	-	-	0.091	Normal
HCO_{3-}	-	-		-	2.25	Normal
pH	pH scale	6.5 - 8.4: normal range		-	7.65	Moderately alkaline

and irrigation water for intended irrigation scheme with reference to standard suitability class. The results revealed that most of the soil physical properties showed variability in their total distribution within the depths of the soil profiles.

Regarding the soil's chemical properties, the soil pH ranged from 7.8 to 8.6 qualifying for moderately to strongly alkaline in reaction. Maximum ECe (7.5 dS/m) and ESP (28.96) values were recorded from the subsurface horizon of profile 1, which is classified as saline-sodic while Profile 2 is classified as non saline non sodic. On the other hand, profiles 3 and 4 were found to be saline and potentially sodic soils. The predominant soluble cations were Ca^{2+}, Mg^{2+} and Na^+ throughout the profile.

In addition, the CEC of the study area indicates the high availability of cation saturation in the study site. On the other hand, the high Percent Base Saturation (PBS) values in all the horizons are used as indicator of soil fertility status and the existence of low leaching processes in the horizons. Moreover, the water sample revealed the water is low in sodicity hazard while EC indicated that the water is medium in soluble salt concentration (salinity hazard) and pH clearly showed that the irrigation water was moderately alkaline.

Hence, the study underscores the need for the scientific reclamation program of salt affected soils and waters for increasing the biological productivity of these habitats. In line with this, a due emphasis be given for frequent monitoring of irrigation waters, selection of suitable verities and crops, removing of excess salts by leaching, adopting judicious means of irrigation and fertilizer application together with the addition of organic manures and fallowing lands with the raclamative grasses; for such sustainable and productive utilization of the land resources, are critical.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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