Full Length Research Paper

Characterizing the Enduring Nature of Dryland Agro-ecosystems: Irrigated and Rain-fed Land Uses in Chamo Sub Basin, Southern Ethiopia

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Abstract

Characterizing soils, land use and providing suggestion for sustainable utilization of land resources in the Ethiopian Rift valley flat plain areas of Lake Chamo Sub-Basin is essential. The objectives of this study were, therefore, to characterize land use constraints and to assess the status of organic matter, macro and micro-nutrients and soil salinity for planning appropriate land management. A systematic soil survey and field observations were made to gather information on land uses. Physiognomic vegetation classification was done in accordance with the FAO classification system, i.e. annual croppings, perennial croppings, grazing land and natural forest. A total of 120 soil samples were randomly collected from different land uses, which were prepared into 12 composites and analyzed in Ethiopia Water Works Design and Supervision Enterprise Laboratory. Organic matter, nitrogen, base saturation, exchangeable (potassium, calcium and magnesium), and phosphorus contents were low in cultivated soils compared to natural forest. Soil salinity was observed in irrigated banana and cotton field soils compared to rain-fed agriculture. Clay, nitrogen, phosphorus and potassium contents were positively correlated with organic matter and electrical conductivity. Also soluble cations and anions were varied along different land uses. Also, organic matter, exchangeable (sodium, calcium), cation exchange capacity, phosphorus and micronutrient contents were positively correlated with soluble salts and electrical conductivity.

Key Words: Rain-fed and irrigated agriculture, Land use types, and soluble salts.

Received: 1 May, 2018; accepted: October, 2018; published: February 2019

1. Introduction

Soil is the primary resource of life on our planet. It is critical to agriculture and therefore to food security and livelihoods. Over the last decade, there has been growing concern about the fertility of soils and – consequently– the sustainability of land use. Soil fertility is usually seen as equivalent to the capacity of the soil to supply nutrients to the plant. In its broadest sense, soil fertility can be seen as a mixture of soil chemical, physical and biological factors that affect the potential of land. In its narrow sense, soil fertility deals only with soil nutrient aspects, and then often only with macronutrients, usually nitrogen (N) and phosphorus (P) and sometimes potassium (K).

Nutrient capital can be defined as the stocks of N, P and other essential elements in the soil that become available to plants during a time scale of 5 to 10 years.It is also the component of overall soil productivity that deals with its available nutrient status, and its ability to provide nutrients out of its own reserves and through external applications for crop production (IFPRI, 2010). It combines several soil properties (biological, chemical and physical), all of which affect directly or indirectly nutrient dynamics and availability.

Core constraints of Ethiopian soils include: depletion of organic matter (OM) due to widespread use of biomass as fuel, depletion of macro and micro-nutrients, removal of topsoil by erosion, change of soil physical properties, and increased soil salinity in time (IFPRI, 2010). Ethiopia is reported to possess over 11 million hectares of unproductive natural salt affected wastelands (Tadelle, 1993). The natural salt affected areas are normally found in the arid and semi-arid lowlands and in Rift Valley and other areas that are characterized by higher evapotranspiration rates in relation to precipitation (PGRC, 1996).

The Great Rift Valley runs from northeast to southwest of the country and separates the western and southeastern highlands and contains 12 Ethiopian Lake basins. With the development and expansion of irrigated agriculture, however, man’s activities are greatly contributing to the buildup and spread of salinity problems. Close to 3 million ha of potentially irrigable land in the different river basins and in the rift valley areas salinity problems is well documented (Tadelle, 1993). Source of salts in saline soils can be the parent material, irrigation water, shallow groundwater, fertilizer and amendments applied to the soils (Selliah and Pathmarajah, 1997).

All soils contain some water-soluble salts, but when these salts occur in amounts that are harmful for germination of seeds and plant growth, they are called saline (Denise, 2003). Salinisation is a dynamic process by which water-soluble salts builds up over the soil. As applied to soils, salinity refers to the soluble plus readily dissolvable salts in the soil or, operationally, in an aqueous extract of a soil sample. Saline soils are often recognized by the presence of white crusts of salts on the soil surface called “White alkali” (soluble salts) and irregular plant growth, however, at “normal” concentrations, soluble salts have little harmful effect on plant growth (Selliah and Pathmarajah, 1997). Irrigation-induced salinity is considered as a pervasive threat to agricultural production and the environment in view of its adverse effects on sustainable use of land and water resources. Salinity is quantified in terms of the total concentration of soluble salts, or more practically, in terms of the electrical conductivity of the solution, because the two are closely related (US Salinity Laboratory Staff, 1954). Electrical conductivity of these soils when a solution extracted from saturated soil is greater than or equal to 4.0 mmhos/cm at 25^0C. The pH is generally less than 8.5; sodium makes up less than 15 percent of the exchangeable cations (U.S. Salinity Laboratory Staff, 1954).

Irrigated and rain-fed crop productions were commonly practiced by smallholder farming communities in the lowland areas of the Chamo Sub Basin (CSB) over the past several decades. With the development of modern irrigation, it is anticipated that salinity would become a problem in the CSB. However, the effects of different land uses and their management practices on the status of soluble salts in the study area have not been studied and have not been well documented. Since the soluble salt is sensitive to changes in the soil environment, problems due to soil salinity and sodicity in soil are commonly evaluated by laboratory testing.

Salinity in the soil varies with time depending on irrigation, rainfall, etc., but it is constant when there are no rain or irrigation and field operations. Thus, measuring salinity after harvest will give a good indication of the level of accumulated salt in the soil. The soil salinity level after the major cultivation season indicates a permanent nature of the salinity problem compared to measurements taken after a minor season (Selliah and Pathmarajah, 1997).

According to the information obtained from Agriculture Development Offices Report in the study area (Arba Minch *Zuria* and Dherashe *Woredas'*, 2012), about 70% of the study area is under cultivation. Increased soil salinity problems (the presence of white crusts on the surface of the soil and irregularity in plant growth) was reported from smallholder farmers of ACB since 2011/12. Studying the status and availability of plant nutrients, particularly**,** NPK in the soils represents a key factor in the overall question of food security where food security is and will remain a serious challenge unless appropriate technical measures are taken to guarantee smallholders' agricultural land use systems. It was also found to be of paramount importance to assess soil salinization problem in relation to differences in land use managements in comparison with natural forest soils. Nevertheless, there were no records of the actual extent of lands affected by salinity, or data that indicated its trend. Therefore, the general objective of this study were to characterize the enduring nature of dryland farming systems. The specific objectives of this study, on the other hand, were to evaluate the effect of land use management on soil fertility and to assess the soil salinisation problem due to concentration of soluble salts in the soils of the different land use practices in CSB.

2. Materials and Methods

2.1 Descriptions of the Study Area

The study area is located within the ACB, comprises three sub-watersheds in Arba Minch *Zuria* and one in Dherashe *Woredas*. Geographically, the area lays between 05°39’36”- 06°12’20” N latitude and 37°24’36” to 37°33’2” E longitude at an altitude of 1100 to 1350 masl. The pattern of the topography of the catchment is composed of flat plain in the west-around Lake Chamo and in the Rift Valley escarpment hills in the west and north. The parent materials of the study area are alluvium along the river and lacustrine along the lakes (Tuma, 2007; GME, 1975; EMA, 1975). The parent material is alluvial river deposits and colluvial materials developed over the old lacustrine deposits.

The mean annual rainfall data of the study area from the years 1987- 2011 were 930 mm. Average maximum and minimum temperature is about 30.5 and 17.4°C, respectively. The rainfall distribution has a bimodal nature with the first and second rainfall during April to May and September to October, respectively. The mean annual evapotranspiration is about 1644 mm. The fact that annual evapotranspiration is greater than annual rainfall indicates that supplementary irrigation is required to grow crops. Since the length of growing season of the study area is 61 days (Tuma *et al*., 2013; Lemma, 1996; EMA,1983), irrigated crop production is common in the area. The major land use/land covers are dominantly intensive perennial and annual crop production. Banana, cotton, mango, avocado and maize are intensively cultivated both under rain fed and irrigated conditions. The land along the river channels and periphery of Lake Chamo is used for grazing. Acacia spp., and *Cordia africana* vegetation covers very few places.

2.2 Soil Sampling and Laboratory Analysis

Standard soil fertility attributes such as soil pH, OC, N, P, K and available micronutrients are important parameters in terms of plant growth, crop production and microbial diversity and function (Doran and Parkin, 1994). Soil OM is a very important fraction of the soil because of its high CEC and because it retains nutrients against leaching losses. According to Waskom *et al*. (2010), the following parameters are included in the basic soil salinity test (1:2 soil-to-water ratio): Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^+), Sodium (Na^+), pH, Electrical Conductivity (EC), Total Soluble Salts (TSS), and Sodium Adsorption Ratio (SAR).

A total of 120 random surface soil samples (0-20 cm) were collected using auger from twelve land use types and were made into 12 composite following the standard procedures of composite soil sampling method. One composite soil sample was made from 10 sub samples which were collected from similar cultivation and land management history. The samples were air dried and passed through 2-mm sieve and analyzed in Ethiopia Water Works Design and Supervision Enterprise laboratory, 2012. For determination of OC and TN, a 0.5mm sieve was used. Particle size analysis was carried out by the modified sedimentation hydrometer procedure (Bouyoucos, 1951). The pH was determined in H_2O and KCl using 1:2.5 soils to solution ratio using pH meter as outlined by Van Reeuwijk (1993). Bulk density (Bd) was estimated from an undisturbed soil sample using a core sampler as described by Blake (1965). The Organic carbon content of the soil was determined using the wet combustion method of Walkley and Black as outlined by Van Ranst *et al*. (1999). Nitrogen was analyzed by the wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Phosphorus content was analyzed using the Olsen method as outlined by Van Reeuwijk (1993) and Jackson (1967). Cation exchange capacity (CEC) was determined by using the 1M ammonium acetate (pH 7) method according to the percolation procedure (Van Reeuwijk, 1993). Available K (K_2O) was by using Ammonium acetate (Anderson, 1973) $CaCO_3$ was determined by Acid neutralization (HCl) method (FAO, 2012). Available micronutrients (Fe, Mn, Zn, and Cu) were extracted by diethylenetriaminepenta acetic acid (DTPA) as described by Tan (1996) and were measured by AAS. Soluble Salts were analyzed by a Water Extraction method (Denise, 2003). Osmotic potential (OP) was also computed (= 0.36 × EC (EC in dS/m)) in addition to ESP (= (Exch. Na/CEC) × 100 (US Salinity Lab Staff, 1954). Data analysis was carried out using SAS 8.2 Version System (SAS, 2001) to correlate the soil fertility factors in relation to land uses.

3. Results and Discussion

3.1 Characterization of Agricultural Land Uses and Vegetation

The studied land uses were generally found within slope range between 1– 2%. The soils of these land uses were young and derived from alluvium deposits. Generally, there is low runoff and good drainage in the study area; this could be due to the slope of the landscape position and depth of the soil. The smallholders' farms in the CSB are dominantly of banana, mango and mixed farming system or agroforestry. The cropping pattern of the area was substantially changed through time, particularly with the modern irrigation systems intervention and subsequent infrastructure development, such as asphalt road facility and land tenuring system during the last 20–25 years, the fruit production was increased and banana became the major crop grown in the irrigated farms (Personal Communication). Improved farming methods such as mulching, intercropping and ridging were practiced in the study area. Also, as we critically observed and collected some data, the dominant land use types were classified as annual farming of maize and/or sorghum system (30%), Perennial Cropping and/or Agroforestry System (50%), Grazing Land and Natural Forest Systems (15%) and others (5%) (Table 1).

During the field survey, the whitish surface crusts of salt precipitates were observed on the surfaces of irrigated cotton field and tamarix-based grazing land uses during dry seasons (Figure 1). Therefore, only silicornica or halophyte plants like Tamarix and salt-tolerant crops like cotton are sparsely grown. It was observed that natural vegetation is sparse and xerophytes are dominant. The salinity of the studied area soils was easily recognized as white crusts of salts on the soil surface which is called "White alkali" and there was irregularly in plant growth (Figure 1), which is in agreement with Denise (2003).

Figure 1. High salt content in the bare spots has prevented the growth of plants, even some salt-tolerant plants.

3.2 Effects of Land Use Management on Soil Physicochemical Properties

i) Soil texture and bulk density

Based on soil particle size distribution data, the textural classes of the studied surface soils were classified as silt, clay loam, silt loam, clay loam, clay, silt clay and loam (Table 1). The distribution of silt, clay and sand did not uniform in all soil matrixes due to the continuous translocation process of silt and clay. The surface soil salinity was more pronounced in medium-textured soils (irrigated cotton field and Tamarix based grazing land) as compared to that of fine-textured soils (Table 1). Since the capillary rise is larger in a medium-textured soil than in a fine-textured soil (Bouksila *et al.*, 2010). However, soil texture was not influenced by land use and management practices. Lower bulk density (1.09 gcm^{-3}) was recorded in Sesbania-based Natural Forest (Table 1), implies greater pore space and improved aeration, creating a choice environment for biological activity (Werner, 1997). The highest bulk density (1.55g/cm^{-3}) was recorded in the Irrigated Cotton Field (Table 1) that may be attributed to poor drainage and compaction, which could limit root growth, gas exchange and availability of less mobile plant nutrients such as phosphorus and potassium (Dolan *et al.*, 1992). However, the bulk densities recorded in the present study was not greater than the critical limits (1.63 g/cm^3) stated by Amusan *et al.* (2001)

due to the fineness of the textural classes of these soils; as a result, they generally had lower bulk densities and better aggregation status.

Table 1. Soil physicochemical properties under surface soils of different LUTs in CSB

Land Use Types	**P-1**	**P-2**	**P-3**	**P-4**	**P-5**	**P-6**	**P-7**	**P-8**	**P-9**	**P-10**	**P-11**	**P-12**
Sand (%)	17.41	11.23	21.52	19.98	20.28	20.03	19.10	9.41	1.86	32.02	9.96	28.36
Silt (%)	49.99	59.18	70.00	50.82	51.33	49.71	27.71	38.20	40.80	52.84	47.88	44.50
Clay (%)	32.60	29.59	8.48	29.20	28.39	30.26	53.20	52.39	57.34	15.10	42.44	27.14
Textural class	SCL	SCL	SL	SCL	CL	CL	C	C	SC	SL	SC	L
BD (g/cm^3)	1.49	1.52	1.35	1.32	1.55	1.52	1.22	1.45	1.19	1.16	1.26	1.09
Exch. Na (cmol(+)kg^{-1})	0.94	1.09	0.52	0.91	1.13	1.00	1.04	0.80	0.88	0.67	0.53	0.72
Exch. K (cmol(+)kg^{-1})	0.31	0.84	0.77	0.78	0.55	0.82	0.62	0.37	0.40	0.35	1.37	0.65
Exch.Ca (cmol(+)kg^{-1})	28.51	23.11	23.32	28.08	26.35	29.96	36.08	32.40	26.16	27.82	18.58	24.19
Exch. Mg (cmol(+)kg^{-1})	6.91	11.34	7.21	8.21	3.02	4.28	9.68	6.91	9.59	6.85	9.07	6.91
Sum Cations (cmol(+)kg^{-1})	36.67	36.37	31.81	37.98	31.05	36.06	47.42	40.48	37.03	35.68	29.55	32.48
CEC (cmol(+)kg^{-1})	37.57	37.91	36.41	39.44	33.81	39.08	47.83	42.73	38.86	37.68	35.69	39.44
Soil OM (%)	2.05	3.74	1.69	4.05	3.09	3.10	4.89	2.26	3.16	1.28	1.60	4.66
Nitrogen (%)	0.13	0.29	0.08	0.23	0.13	0.12	0.37	0.12	0.20	0.05	0.12	0.33
P_2O_5 (mg/kg)	63.47	117.84	56.06	138.04	124.40	96.76	75.58	57.47	148.49	54.60	39.28	251.34
K_2O (mg/kg)	132.74	304.72	334.65	320.14	226.44	391.96	217.38	161.37	186.51	190.82	546.59	216.03
Fe (ppm)	9.94	28.95	14.24	19.07	13.20	16.31	10.48	10.92	6.41	12.11	13.69	40.25
Mn (ppm)	2.46	4.51	2.15	3.01	3.10	13.09	12.07	9.48	4.87	4.33	13.03	0.87
Zn (ppm)	0.66	1.24	0.71	1.25	1.06	0.84	0.96	0.65	0.79	0.79	0.96	1.27
Cu (ppm)	0.58	1.26	0.50	1.04	1.06	1.05	0.92	1.01	0.87	0.79	1.75	1.10

Land Use Types classified based on FAO (2006): Irrigated Maize Field= P-1; Irrigated Banana Field= P-2; Acacia Based Natural Forest= P-3; Irrigated Banana Field= P-4; Irrigated Cotton Field =P-5; Tamarix Based Grazing Land =P-6; Acacia Based Grazing Land =P-7; Irrigated Maize Field =P-8; Irrigated Banana Field= P-9; Rain-fed Moringa Field= P-10; Rain-fed Sorghum Field =P-11, and Sesbania Based Natural Forest= P-12. Also the soil textural classes were described as: C=clay, CL=clay loam L=loam,; SC= Silty clay, SCL= Silty clay loam, SL= Silt loam.

ii) Exchangeable bases (K, Ca, Mg), CEC and PBS

The exchange complex of the soils is dominated by Ca followed by Mg, K and Na (Table 1). Exchangeable Ca^{2+} in the surface soils of the studied land uses ranged from 18.58- 36.08 cmol (+)kg^{-1} i.e., all studied land uses were rated as high to very high (Tables 1). For most crops, the recommended threshold level of Ca^{2+} is 5-10 cmol (+) kg^{-1}. Similarly, Mg^{2+} content was high to very high in all soils with values ranging from 3.02- 11.34 cmol (+) kg^{-1}. For most of the crops, the recommended threshold level of Mg^{2+} is 1.0 -3.0 cmol (+) kg^{-1}. These results are in agreement with Tuma (2007) findings on fluvial soils in Gamo Gofa zone, Ethiopia, that Ca followed by Mg, K, and Na in the exchange site of soils is favorable for crop production. Though different crops have different optimum ranges of nutrient requirements, the response to calcium fertilizer is expected for most crops when the exchangeable calcium is less than 0.2 cmol (+) kg^{-1}of soil, while 0.5 cmol (+) kg^{-1}of soil is the deficiency threshold level in the tropics for Mg (Landon, 1991). Exchangeable K^+ levels ranged from 0.31-1.37 cmolkg^{-1} in the soils (Table 1) with a mean value of 0.43 cmol (+) kg^{-1}. The recommended threshold level of exchangeable K^+ for most crops is 0.3-0.6 cmol (+) kg^{-1}. This result generally suggests that exchangeable K^+ is not a limiting mineral element to crop production except in Moringa field. Clay was negatively ($r = -0.08$) correlated with exchangeable K (Table 3), indicating that the negative association of clay with the exchangeable K^+ in the studied soils. The CEC values ranged from 33.81 to 47.83 cmol (+)kg^{-1} with a mean value of 38.87 cmol (+)kg^{-1} (Table 1), which is high to very high range in the studied soils indicates cation exchange is the major nutrient reservoirs of K^+, Ca^{2+} and is also important in holding N in the ammonium (NH_4^+) form. Values in excess of 10 cmol (+) kg^{-1} are considered satisfactory for most crops, which is in agreement with FAO (2012). The higher the CEC, the more capable the soil can retain mineral elements. Moreover, PBS of the soils ranged from 82.33- 96.29, which indicates a high fertility of the soil because many of the “bases” that contribute to it are plant nutrients. Also, soils with high PBS are considered more fertile.

iii) Organic matter (OM) and total nitrogen (TN)

The status of OM and TN in the soils of the study area is given in Table 1. Soil organic matter contents of surface soils varied from 1.28–4.89% along land uses (Table 1). SOM content of soils is categorized as very low (<1%), low (1-2%), medium (2-3 %), high (3-5%) and Very high (>5%) (NFIU, 1989). According to these categories, most of the SOM content in the studied soils is in the low ranges. This indicates that for both rain-fed and irrigated farms, without application of nitrogen containing fertilizers, no adequate yields can be achieved. The inherent SOM content was rated as low for Rainfed Sorghum and Moringa Fields whereas medium for all other conventional fields. The lower value of SOM in the moringa field soils was due to intensive harvest of moringa leaves for selling and home consumption. According to the results of fertilizer trials carried out in Ethiopia (NFIU, 1989), the critical SOM values for the common cereals grown are 2.5% for barley and wheat; 3.0% for maize; 2.0% for sorghum and teff.Low organic matter containing soils are often low in zinc and SOM may form natural chelates aiding in maintaining iron in a soluble form. High SOM content decreases copper availability due to strong bonding of copper to OM and may tie up manganese into unavailable organic complexes (Regis, 1998).

The TN content of the surface soils ranged from 0.05 in the moringa field to 0.37% in NF (Table 1) with a mean value of 0.18%. The TN content of the surface soils is categorized from low to medium except for NF, which was at high range. The distribution pattern of TN across land uses was similar to that of SOM, since SOM contents are a good indicator of available nitrogen status in the soil. The difference in SOM and TN content among the land uses could be attributed to the effect of variation in land use management. Intensive and continuous cultivation aggravated SOC oxidation, resulted in reduction of TN as compared to NF. As per the suggestions made by Havlin *et al*. (1999), TN content of soils is categorized as low (<0.15%), medium (0.15- 0.25%) and high (>0.25%) Accordingly, the TN content of the studied soil can be rated as low medium. Positive and strong correlation (r = 0.91**) was found between SOM and TN. The results are in accordance with the findings of Tuma (2007), who reported that intensive and continuous cultivation, forced oxidation of SOC and thus resulted in reduction of TN. Thus, the temporal changes in TN were similar to those of OC content for surface soils with a depletion rate of about 2.4% per year for maize field; 2.4 to 2.1% of monoculture banana, and 2.3 to 2.1% for mixed fruit crop land when compared to the virgin land (Tuma et al., 2013). The C:N ratio of surface soils ranged from 8.0 to 15.6 suggesting that the studied soils had a moderate to good quality SOM. It is generally accepted that C: N ratios between 8 and 12 are considered to be the most favorable for crop production, implying a relatively fast mineralization of nitrogen from the OM. The observed C: N ratio status in studied sites can be considered as suitable for plant growth. However, lower values of C:N ratio is due to lower content of OC and TN.

iv) Available phosphorus (P2O5) and potassium (K_2O)

The P_2O_5 content of the surface soils ranged from 39.28 to 251.34 mg/kg (Table 1) with a mean value of 101.94 mg/Kg, which is in a very high range for all land uses. P_2O_5 contents in surface soils can be categorized as very low (<5), low (5- 9), medium (10- 17), high (18- 25) and very high (>25) (Havlin *et al*., 1999). Higher P_2O_5 values in surface soils might be attributed to preferred range of soil pH (neutral and near neutral), increased solubility of Ca phosphate in calcareous soils, greater diffusion of P in flooding conditions (since flooding and soil and water conservation prevalent at the study site), the mineralization of OM, and differences in land use management, which is in agreement with Havlin *et al*. (1999). The high and positive correlation (r = 0.91) obtained between TN, OC and P_2O_5 indicate that SOM highly contributes to P_2O_5 of soils. Based on the above results, it is not compulsory to apply P_2O_5 containing fertilizers in all the land use systems studied.

In the studied LUTs, the K_2O content of the surface soils ranged from 132.74 to 546.59 mg/kg of soil (Table 1) with a mean value of 269.11 mg/kg, which is medium to very high range. The positive and very high correlation (r= 0.96) obtained between exchangeable K and K_2O (Table 3) indicates exchangeable K highly contributes to K_2O content of soils. The negative correlation (r = -0.07) obtained between clay and K_2O indicates that K_2O availability is affected by clay contents, the intensity of potassium rich clay minerals (e.g. illite, micas, and feldspars) decomposition in these soils. The negative and significant correlation (r = -0.57) obtained between exchangeable Ca and K_2O (Table 3) indicates that exchangeable Ca has an antagonistic effect on K_2O availability in the studied soils. Basic elements like K removed from the soil with an intensive harvest of Moringa leaves.

The K_2O content in (gkg^{-1}) can be rated as very low (<120), low (121- 240), medium (241- 300), high (300- 360) and very high (>360)) (Tandon, 2005). Cation exchange is the major nutrient reservoirs of K^+, Ca^{2+} and is also important in holding N in the ammonium ($NH4^+$) form. Restoration of vegetation increases the accumulation of soil K because the nutrient-rich branches and coarse litter fraction are all-important nutrient sources. It is generally accepted that response to K fertilizers is likely when a soil has an exchangeable K value of <0.2 cmol (+) kg^{-1} and unlikely when it is above 0.4 cmol (+)kg^{-1} soil. Thus exchangeable K^+ in the soils rated as very low (<0.2), low (0.2- 0.3), medium (0.35- 0.6), high (0.6- 1.2) and very high (>1.2) (FAO, 2006b). In dry areas (where there is less soil solution), exchangeable K tends to be more important than dissolved K. Because K dissolves readily, it is highly mobile in the soil. However, it can get trapped between layers of expanding clays.

v) Status of available micronutrients

The inherent concentration of available micronutrients (Fe, Mn, Zn, Cu) in studied surface soils was found to be Fe> Mn> Zn> Cu in almost all land uses (Table 1). The available Fe contents of the soils widely varied from 6.41 to 40.25 ppm (Table 1) with a mean value of 16.30 ppm. The available Mn contents of the soils widely varied from 0.87- 13.09 ppm with a mean value of 6.08 ppm. The available DTPA Zn contents of the soils widely varied from 0.65- 1.27 ppm with a mean value of 0.93 ppm. The available DTPA Cu contents of the soils widely varied from 0.50- 1.75 ppm with a mean value of 0.99 ppm. According to critical values of available micronutrients (Fe, Mn, Zn, and Cu) set by Havlin *et al.* (1999) and Lindsay and Norvell (1978), the amounts of Fe, Mn, Zn and Cu in the surface soils of the study area were not deficient in crop production. Mn in very isolated case, for example, in Sesbania-based natural forest was deficient of some other micronutrients (Table 1). Also, these results are in agreement with various works which stated that Zn contents are variable and, Fe and Mn contents usually at an adequate level in Ethiopian soils (Desta, 1982; Fisseha, 1992; Abayneh, 2005). Fe was negatively correlated (r = -0.35) with Mn (Table 3) that Fe availability decreased as Mn increases in the soils. Mn was negatively correlated (r = -0.22) with Zn that Mn availability decreased as Zn increases in the soils. As described in Table 3, Cu was positively correlated with Fe, Mn and Zn. Specifically, Fe was positive and very significantly correlated with Zn (r = 0.75). Generally, these results in line with Regis (1998) that applications of iron and zinc may reduce manganese availability in the soils.

3.3 Soil Salinity as Influence of Land Use Managements

i) Electrical conductivity (EC), soil pH and calcium carbonate ($CaCO_3$)

The total soluble salt content of the study area soils, ranged from 0.19 in the rain-fed Moringa field to 16.86 in dSm^{-1} in irrigated cotton field (Table 2). The soils of irrigated cotton field and Tamarix-based Grazing field was falling in the range of salt affected the quality with poor soil physical properties (Table 2). This indicates the moderate level concentration of total salt in soil, and a problem of soil salinity in the area. The higher the concentration of soluble salts in aforementioned land uses depends on the ineffectiveness of drainage, water management, and OM application. The lower values of EC in the rain-fed agricultural soils were due to the positive effect of *Moringa* and sorghum plantations on re-structuring of topsoil layer, gradual leaching of salts from the root zone, and free drainage conditions.

Table 2. Status of Soluble Salts in Surface Soils under different LUTs, ACB, 2012

Variable/LUTs	**P-1**	**P-2**	**P-3**	**P-4**	**P-5**	**P-6**	**P-7**	**P-8**	**P-9**	**P-10**	**P-11**	**P-12**
EC (dSm^{-1}) (1:2)	0.21	0.23	0.19	0.49	16.86	9.85	0.43	0.21	0.26	0.21	0.26	0.85
OP (bars)	0.08	0.08	0.07	0.18	6.07	3.55	0.16	0.08	0.09	0.08	0.09	0.31
pH-H_2O (1:2.5)	7.28	7.55	6.84	7.62	6.82	8.24	7.65	7.22	7.35	7.47	6.87	6.57
P^H-KCl (1:2.5)	6.47	6.53	6.10	7.02	6.04	7.33	7.00	6.48	6.59	6.75	6.12	5.82
$CaCO_3$ (%)	5.58	2.28	5.24	5.89	4.68	6.38	3.20	8.43	5.84	4.97	3.14	6.44
ESP (%)	2.50	2.88	1.42	2.31	3.33	2.55	2.18	1.87	2.27	1.78	1.47	1.83
Soluble Na^+	0.47	0.43	0.53	0.67	0.97	2.24	0.84	1.03	0.75	1.37	0.50	0.44
Soluble K^+	0.09	0.20	0.08	0.37	1.62	0.41	0.30	0.22	0.28	0.30	0.18	0.74
Soluble Ca^{2+}	0.80	1.00	1.20	0.80	1.60	1.60	2.20	1.40	1.60	1.40	0.80	1.80
Soluble Mg^{2+}	0.40	0.40	0.20	0.40	0.60	1.00	2.00	0.40	0.40	0.40	0.40	0.60
Sum of Cations	**1.76**	**2.04**	**2.01**	**2.25**	**4.76**	**5.24**	**5.34**	**3.05**	**3.03**	**3.47**	**1.88**	**3.59**
Soluble CO_3^{-2}	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00
Soluble HCO_3^{-1}	0.44	0.66	0.44	0.88	0.22	0.00	4.40	1.98	1.76	2.20	0.88	1.10
Soluble Cl^-	0.14	0.14	0.14	0.14	0.28	0.28	0.14	0.28	0.56	0.84	0.14	0.14
Soluble SO_4^{-2}	0.90	0.94	1.35	0.75	3.73	3.79	0.59	0.68	0.42	0.27	0.56	0.87
Soluble NO_3^{-1}	0.23	0.19	0.05	0.41	0.38	0.30	0.32	0.13	0.23	0.07	0.19	1.27
Sum of Anions	**1.71**	**1.93**	**1.98**	**2.18**	**4.61**	**4.81**	**5.45**	**3.07**	**2.98**	**3.39**	**1.77**	**3.38**
Cations/Anions ratio	1.03	1.06	1.02	1.03	1.03	1.09	0.98	0.98	1.02	1.02	1.06	1.06
Ca^{2+}/Mg^{2+}	2.00	2.50	6.00	2.00	2.67	1.60	1.10	3.50	4.00	3.50	2.00	3.00
$(Ca^{2+}+ Mg^{2+})/(Na^{+}+ K^{+})$	3.57	3.97	21.42	1.92	1.03	0.61	1.26	2.80	3.20	2.10	2.94	2.54
Cl^-/SO_4^{2-}	0.16	0.15	0.10	0.19	0.08	0.07	0.24	0.41	1.33	3.11	0.25	0.72

Soluble salts (meq/l) were measured in 1:5 ext.

The soils of the study area were in several ranges of the EC from 0.19- 16.86 in dSm^{-1}. 83% of these soils were classified as non-saline (EC < 2 dS/m) (Table 2), which has little or no effect on the growth and yield of plants. 17% of the study area soils were classified as strongly saline (EC between 8-16 dS/m) (Table 2), this level salinity affects tolerant plants. Most saline agricultural soils have EC less than about 20 dS/m in the surface area of the root zone. These results are in harmony with USDA soil salinity classification (U.S. Salinity Laboratory Staff, 1954): non-saline (0–2 dS/m), slightly saline (2–4 dS/m), moderately saline (4–8 dS/m), strongly saline (8-16 dS/m) and very saline (>16 dS/m). These reveal that under climate change conditions we will need to increase the irrigation rates with regard to the current water applications in order to combat the likely effect of climate change on the irrigation crops in the lowland areas. High salinity causes plant cell dehydration, reduced plant growth and possibly death in less tolerant plants, while tolerant ones may survive in a number of physiological ways (Joe, 2002). As indicated in Table 3, soil salinity measured as EC was positive and significantly correlated (r= 0.60) with soluble cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) indicating the strong association of EC with soluble cations in soil salinisation. Also EC was positively correlated (r = 0.56) with soluble anions ($C1^-$, SO_4^{2-}, HCO_3^-, and NO_3^-) indicating the good association of EC with anions in soil salinisation. Similarly, soluble cations were positive and very significantly correlated (r= 0.99) with soluble anions.

The pH-H_2O values of soils were higher than 6.7 and lower than 8.5 except for Sesbania Based Natural Forest, which was 6.6 (Table 1) indicating the presence of calcium carbonate ($CaCO_3$) in the soils. The soil pH values classified as moderately acidic to moderately alkaline (Table 2), which is in the preferred range for most crops. As a result of the small energy of adsorption of Na, it is more likely to exist in the soil solution and be removed from the soil by leaching (Foth, 1990). In all surface soil pH (pH-H2O - pH-KCl) values were positive, ranging from 0.60-0.91. The positive _pH values indicated the presence of net negative charges in soils; which increases the ability to hold onto cations at negatively charged sites within the soil and show the presence of weatherable minerals (Buol *et al*., 2003). As a result, the negative correlation was obtained between pH (pH-H2O and pH-KCl) with available K_2O and exchangeable K_2O (Table 3).

The surface soils of all studied land uses had 2.28–8.43% $CaCO_3$ equivalent, which is in the optimum suitability range for crop production (Table 1). Low levels of $CaCO_3$ (< 5%) enhance soil structural development and are generally beneficial for crop production in reducing soil acidity, but at higher concentrations they may induce iron deficiency and when cemented limit the water storage capacity of soils (FAO, 2012). The pH-H_2O and $CaCO_3$ were positively correlated with soluble cations and anions. In contrast, the negative correlations between pH-H_2O and $CaCO_3$ (r = -0.09), indicating a weak relationship between $CaCO_3$ and pH-H_2O in soil salinisation (Table 3).

ii) Soluble salts (Cations and Anions)

Total Soluble Cations (TSC) and Total Soluble Anions (TSA) are reported as meq/L and obtained from detailed chemical analyses of cations and anions. The TSC/TSA ratio of all studied land use, soils were greater than about unity (Table 2), which indicates that the balance of the charges (cations and anions) in the soils and major ions have been chemically analyzed accurately in the laboratory. Since salinity is a heterogeneous mix of electrolytes. Most soils of Irrigated Banana and Irrigated Cotton land uses had $(Ca^{2+}+Mg^{2+})/(Na^+ +K^+)$ ratios in between 1 and 4 and the Ca^{2+}/Mg^{2+}-ratios are ≥ 1 but varied (Table 2). It is widely believed that these soils are dominated by Ca and Mg over Na and K and remained stable structure, even when the salts are flushed out of the soils, for example in Irrigated Cotton and Tamarix Based

Grazing land uses (Table 2). Therefore, these soils are characterized as calcium-dominated saline soils (FAO, 2001). Variations of these in Irrigated Banana and Cotton land uses is probably the presence of groundwater table at a depth less than two meters. Excess Ca is usually associated with excess calcium chloride and sulphate in the soils. Excess Ca was prevalent in saline soils, in which excessive amounts of gypsum ($CaSO_4.2H_2O$), calcium chloride ($CaCl_2.6H_2O$) or soluble calcium salt have accumulated through the capillary rise from the ground water. Also the presence of $CaCO_3$ may lead to higher values of soluble and total Ca, and Mg in the drier area soils. Soils of other land uses had <0.05 Cl^-/SO_4^{--} ratios except in Irrigated Banana (P-9) and rain-fed Moringa land uses (Table 2), which are non-sulphate soda soils in accordance with FAO (2001). These two land uses had Cl^-/SO_4^{--} ratios in between 1 and 5; as a result these soils are dominated by chloride ions. Therefore, these soils are characterized as Chloride soils. The salt types found in such soils are chlorides of calcium and magnesium (Bonnie *et al*., 2002; Joe 2002).

Notably, the anions are equally important in affecting the growth potential of the plants if they are in the order of importance $HCO_3^- + CO_3^{2-} > SO_4^{2-} > Cl^-$ (FAO, 2001). As is shown in Table 2, though all the anions are not in safe range except in Sesbania-based Natural Forest the anionic composition of the soils of the study areas, which is in the order of $HCO_3^- + CO_3^{2-} > Cl^{2-} > SO_4^{2-}$ except for Irrigated Banana, Irrigated Cotton, Tamarix-based grazing, and Acacia-based grazing land uses) (Table 2). It is in order of $SO_4^{2-} > HCO_3^- + CO_3^{2-} > Cl^-$ which indicates nutritional imbalance in the soils (FAO, 2001). Generally, the soluble salts that occur in soils consist mostly of various proportions of the cations calcium (Ca^{2+}), magnesium (Mg^{2+}) and sodium (Na^+), and the anions chloride (Cl^-), and sulfate (SO_4^{2-}). Constituents that ordinarily occur only in minor amounts are the cation potassium (K^+) and the anions bicarbonate (HCO_3^-), nitrate (NO_3^-) and carbonates (CO_3^{2-}) but soluble carbonates are almost invariably absent.

The osmotic potential/pressure (OP) was 0.07 in Acacia-based Natural Forest to 6.07 bars in Tamarix-based grazing land. The distribution pattern of OP across land uses was similar to that of EC and ESP. This is because EC saturation is a good indicator of OP status in the soil. Generally, the higher values of OP in Irrigated Banana and Cotton Fields imply decreasing in availability of water to plants resulting in water stress and reduced crop yield. The exchangeable sodium percentage (ESP) was 1.42% in Acacia-based Natural Forest to 3.33% in Tamarix-based grazing land indicating no adverse effect of sodicity in soils which, having ESP value is <15 (Havlin *et al.*, 1999). Secondary salinization occurs when significant amounts of water are provided by irrigation, with no adequate provision of drainage for the leaching and removal of salts, resulting in the soils becoming salty and unproductive.

Table 3. Simple correlation surface soil between land use and soil properties

	Fe	Mn	Zn	Cu	Ec	Silt	Clay	Na	K	Ca	Mg	CEC	PBS	TN	OC	AP	AK	CaCO3	PH(H2O)	PH(KCl)	Cations	Anions
Fe	1	-0.35	0.75	0.31	-0.07	0.2	-0.35	-0.01	0.28	-0.35	0.1	-0.07	-0.47	0.51	0.5	0.72	0.12	-0.07	-0.26	-0.33	-0.06	-0.12
Mn		1	-0.22	0.49	0.06	-0.48	0.53	0.03	0.42	0.27	0.08	0.42	0.04	-0.03	-0.03	-0.48	0.48	-0.13	0.48	0.47	0.38	0.38
Zn			1	0.52	0.12	0.02	-0.12	0.29	0.42	-0.28	0.21	0.05	-0.21	0.68	0.69	0.69	0.25	-0.38	-0.1	-0.12	0.06	0.04
Cu				1	0.1	-0.18	0.28	-0.03	0.74	-0.42	0.2	-0.12	-0.42	0.21	0.14	0.08	0.66	-0.36	-0.08	-0.13	-0.02	-0.05
Ec					1	0.08	-0.14	0.5	0	0.06	-0.78	0.38	-0.06	-0.17	0.08	0.12	0.07	0.04	0.04	-0.02	0.6	0.56
Silt						1	-0.84	-0.29	0.23	-0.62	-0.14	-0.74	-0.29	-0.48	-0.47	-0.12	0.31	-0.15	-0.17	-0.27	-0.5	-0.54
Clay							1	0.29	-0.08	0.37	0.35	0.55	0.3	0.37	0.31	0	-0.15	0.07	0.17	0.2	0.19	0.23
Na								1	-0.29	0.49	-0.1	0.22	0.65	0.44	0.57	0.23	-0.34	-0.15	0.48	0.41	0.47	0.47
K									1	-0.59	0.24	-0.23	-0.57	0.08	0.02	-0.9	0.96	-0.5	-0.07	-0.11	-0.19	-0.22
Ca										1	-0.15	0.78	0.71	0.22	0.34	-0.13	-0.57	0.34	0.54	0.62	0.6	0.64
Mg											1	0.36	0.19	0.48	0.22	-0.03	0.11	-0.49	0.09	0.08	-0.47	-0.42
CEc												1	0.45	0.56	0.53	0	-0.31	0.11	0.4	0.49	0.4	0.45
PBs													1	0.13	0.17	-0.26	-0.54	-0.03	0.66	0.68	0.16	0.2
TN														1	0.93	0.61	-0.14	-0.31	0.03	0.04	0.25	0.27
OC															1	0.7	-0.16	-0.11	0.16	0.18	0.44	0.44
AP																1	-0.21	0.19	-0.24	-0.25	0.18	0.15
AK																	1	-0.4	0.04	0.01	-0.16	-0.21
CaCO3																		1	-0.02	0,04	0.08	0.07
pH(H2O)																			1	0.97	0.33	0.32
pH(KCl)																				1	0.36	0.35
Cations																					1	0.99
Anions																						1

*, **, *** Significant at 0.05, 0.01 and 0.001 or than probability levels, respectively.

Furthermore, soil test categories in Table (1 and 2) can be explained as “Below Optimum” (very low, low, medium) levels of nutrients are considered deficient and will probably limit crop yield. There will have a moderate to high probability of an economic crop yield response to additions of that nutrient. “Optimum” (sufficient, adequate, proportional) levels of nutrients are considered adequate and will probably not limit crop growth. For example, it is not compulsory to apply P2O5 containing fertilizers in all the land use systems studied. There is a low probability of an economic crop yield response to additions of these nutrients. “Above optimum” (high, very high, and excessive) levels of nutrients are considered more than adequate and will not limit crop yield. There is a very low probability of an economic crop yield response to additions of these nutrients. At very high levels there is the possibility of a negative impact on the crop if nutrients are added.

Conclusions and Recommendations

The results of 120 randomly collected soil samples from different land uses, particularly, from irrigated and rain-fed agricultural fields revealed that Most of the important soil quality indicators were significantly influenced by different land use systems, for example, SOM was depleted from most of surface soil cultivated land uses. Nutrient concentrations in most of the soil showed that annual cropping has less nutrient concentrations compared to perennial cropping system in irrigated agriculture. Similarly, perennial cropping system has less nutrient concentrations than rain-fed agriculture. In addition to this, this study revealed that salinity is gradually building up in soils of CSB because of the evaporation of the soil moisture from the surface of the soils and the nature of alluvial plain (Table 1), which implies that LGP of the area is 61 days and evapotranspiration is greater than rainfall. The studied soils indicated that, about 83% are non-saline and 17% saline. These were caused by poor quality irrigation water, internal soil drainage problems and soil parent materials in CSB.

Soluble salt concentrations in most of the soil showed that annual cropping land has less compared to perennial cropping in irrigated agriculture and less than under rain-fed agriculture. The perennial cropping system improves soil productivity by reducing the concentration of soluble salts because of its long fallow period and reestablishment of deep-rooted perennial plants. For example, bananas return substantial quantities of OM to the soil and protect soil against erosion as compared to annual cropping system. The rain-fed agriculture is an encouraging effect on the reduction of soluble salts. This study revealed that most of the soil properties are influenced by differences in land use managements. Therefore, reducing intensive cultivation and incorporating management practices that improve soil organic matter like leguminous could replenish the degraded soil properties for sustainable agricultural production and productivity in the study area. Hence, it is recomnded to include management practices that minimize the concentration of soluble salts in both systems, when the land is continuing to be cultivated. Moreover,seasonal analysis of soil characteristics is needed because the salt content of the soil differs from season to season. Furthermore, research on identification of plants, which are found around the study area for the improvement of the salt affected soil, should be conducted.

Conflicts of Interests

The authors declare that there is no conflict of interests.

Acknowledgements

The authors thankfully acknowledge Arba Minch University for its financial support. They also thank the farmers who allowed them to take the soil samples from their farms and thos who provided them with the necessary data.

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