

Impacts of Soil Salinity/Sodicity on Soil-Water Relations and Plant Growth in Dry Land Areas: A Review

Birhane Hailu and Hagos Mehari
Ethiopian Institute of Agricultural Research, Mekhoni Agricultural Research Center,
Mekhoni, Tigray, Ethiopia

Abstract

Soil salinity/sodicity is the major problem in irrigated and rain-fed areas and are a continuous threat for the sustainability of agricultural production. The presence of salt affected soils has been identified as a major process of land degradation and the greatest cause of declining productivity by causing a detrimental effect on biological, physical and chemical properties of the soil system. Therefore, the objective of this topic is to review the impacts of salinity/sodicity on soil- water relations and plant growth in dry land areas in relation to their extent, distribution and development so as to manage and efficiently utilize the limited natural resources under irrigation and rain-fed farm lands. Land degradation by salinization is often found in Arid and Semi-Arid lands where irrigation of unsuitable soils or with poor quality water is a common practice. Moreover, dry land salinity is also mainly a function of rising groundwater tables, caused by increased recharges. Soils having soluble salts in solution and/or Na^+ ions or both on exchange sites exceeding certain limits that can adversely affect soil plant health by disturbing the biological, physical and chemical properties of the soil to the lower limit are classified as saline, sodic and saline sodic by taking into consideration of their pH, ECe and ESP. High levels of salinity have negative impact and potentially lethal effects on plants growth. On the other hand, high sodium concentration causes sodium-induced dispersion like reduced infiltration, reduced hydraulic conductivity and surface crusting while salts like calcium and magnesium, do not have this effect because they are smaller and tend to cluster clay particles and keep the soil to be flocculated since they compete for the same spaces as sodium to bind clay particles and reduce the amount of sodium-induced dispersion. High salt levels in the soil affects the nutrient balance in the plant or interfere with the uptake of some nutrients. Salt affected soils restricts plant growth and nutrient uptake due to osmotic forces.

Keywords: Salt Affected Soils, Dry land, Soil-Water, Soil Properties

DOI: 10.7176/JNSR/12-3-01

Publication date: February 28th 2021

Introduction

The majority of the population in the arid and semi-arid areas depend on agriculture and pastoralism for subsistence. Agriculture and postoralism in these areas are face many constraints due to erratic rainfall patterns, torrential rainfall which is the major cause of run-off, high rate of evapotranspiration further reducing yields. Within these areas, weeds growing more vigorously than cultivated crops and competing for scarce reserves of moisture. Low organic matter levels and high variabilities in responses to fertilizers are also the characteristic features of soils of arid and semi-arid areas (CASL, 2006). Various environmental stresses like high winds, extreme temperatures, soil salinity, drought and flood have affected the production and cultivation of agricultural crops in dry land areas. Among these, soil salinity is one of the most devastating environmental stresses, which causes major reductions in cultivated land area, crop productivity and quality (Shahbaz and Ashraf, 2013).

Irrigation agriculture played an important role in ensuring food security for billions of people in arid and semi-arid areas in the past. However, their current and future state of affairs leaves much to be desired due to low crop yield and land degradation (Mason, 2002). The concept of integrated catchment management in dry land areas are often neglected when expanding agricultural development. The productivity of soils is increasingly affected by highly unfavorable drainage conditions, improper farming system and inappropriate irrigation practices that have caused widespread of water logging. Thus, lack of sufficient information about soil characteristics, inappropriate soil, irrigation and drainage management have been resulted in rapid land degradation (Khouri, 2003).

Salinization has been identified as a major process of land degradation and the greatest cause of declining productivity in many irrigated lands (Akram *et al.*, 2010; FAO, 2009). Globally, about one third of agricultural lands are becoming saline and extend to more than one hundred countries of different climates (Squires and Glenn, 2004) and nowadays it is estimated that, 400 Million hectares of the world's land is affected by salinization and its cost to agriculture is estimated conventionally to be about twelve billion US dollars a year and is expected to increase as soils are further affected due to irrigation water challenges (Bot *et al.*, 2000).

Land degradation by salinization is often found in arid and semi-arid lands where irrigation of unsuitable soils or with poor quality water is a common practice (FAO, 2000). Poor irrigation agriculture in arid and semi-arid regions results in land degradation through soil salinity and sodic soil developments in different parts of the world.

Hence, the study of arid lands and salt affected soils has been an important topic for modern agricultural management and particularly for poor countries like Ethiopia where agriculture is the backbone of its economy while arid and semi-arid climatic zones occupy over 60% of the total land area (Awulachew *et al.*, 2007). The total land area covered by salt affected soils in Ethiopia is estimated at about 11,033,000 hectares and occur for the most part of the rift valley zone and nowadays, soil salinity has become an important problem in irrigated soils of Ethiopia (Mohamed and Tessema, 2013).

Soil salinity is a serious problem in areas where groundwater of high salt content is used for irrigation. The most serious salinity problems are being faced in the irrigated arid and semi-arid regions of the world and it is in these very regions that irrigation is essential to increase agricultural production to satisfy food requirements. However, irrigation is often costly, technically complex and requires skilled management. Failure to apply efficient principles of water management may result in water logging and salinity problems which reduce the soil productivity and eventually leading to loss of arable land (FAO, 1998). Dry land salinity is also mainly a function of rising groundwater tables, caused by increased recharge following replacement of native vegetation with annual/pasture systems (Rengasamy, 2002).

Effective control of salt affected soils requires a good knowledge of the cause, extent, distribution and its impact on soil – water characteristics and plant production. Moreover, its problem is never a static soil behavior and use of poor quality of water in agriculture lead to degradation of soil properties (Bandari *et al.*, 2012). Hence, spatial and temporal variability of soil properties are important issues to be considered in soil management. Furthermore, reliable and up-dated information about the soils salinity status in relation to their impacts on soil-water plant is required to effectively manage the limited natural resources (Fentaw *et al.*, 2006; Hailay *et al.*, 2000; Yonas *et al.*, 2005). Therefore, the objective of this topic is to review the impacts of soil salinity on soil – water relations and plant growth in dry land areas.

Impacts of Soil Salinity/Sodicity in dry Land Areas

Characteristics of Dry Land Areas

Dry lands cover about 41% of earth's land surface and are inhabited by about one third of world population (White *et al.*, 2002). Dry land area is characterized by a rainfall of low, erratic and scattered and is concentrated in a few heavy storms. The rains may be delayed and droughts are frequent. Rains may occur at times when they do not benefit crops in the field. Dry land areas are those with less than three months of enough moisture to support plant growth, with an average temperature of at least 27°C and also the rainfall is less than 40% of the potential evapotranspiration. In general, arid and semi-arid zones are characterized by low erratic rainfall of up to 700 mm per annum, periodic droughts and different associations of vegetative cover and soils (IIRR, 2002).

Dry lands are a vital part of the earth's human and physical environments that encompass rangelands, arable lands, forests and urban areas (Koochafkan and Stewart, 2008). Two broad types of dry land can be distinguished: arid and semi-arid, sub-humid and wetter dry lands. The dividing line is often put at 600 mm of rain per year (IIRR, 2002). The arid, semiarid and dry sub-humid lands of Ethiopia occupy approximately 65% of the total land mass (close to 700,000 km²) of the country and 46% of the total arable land (Yonas, 2001).

The soils are thin and easily eroded. They are low in organic matter (less than 2%) and dry out quickly. Within the dry lands there are scattered patches with better soils or a wetter climate. In addition, the vegetation is sparse, leaving a large proportion of the soil surface exposed. This allows rain to compact the surface, forming a crust which stops water from seeping into the soil. The water runs off instead, causing erosion and flash floods and is also responsible for the formation of salinity since evapotranspiration is higher than precipitation. Most of the cropping in the arid and semi-arid regions continues to be under rain fed conditions even if irrigation practice is exercised in some areas (IIRR, 2002).

Development of Soil Salinity/Sodicity

Soil salinity is an increasingly worldwide problem in crop production which is predominantly induced by irrigation in arid and semiarid regions (irrigation agriculture). About one-third of the irrigated land on earth is affected by salinity. Evapotranspiration removes water from the soil and thus solutes gradually start to concentrate in the soil surface, in particular when salts cannot be flushed out by a drainage system. Saline soils are characterized by high salt levels in the soil profile. Different ion species (Na⁺, Cl⁻, HCO₃⁻, PO₄³⁻, Ca²⁺, Mg²⁺, SO₄²⁻ and borate) with changing composition are present often in concentrations affecting crop growth (Konrad, M. 2001).

Soil quality varies spatially from field to larger region scale and is influenced by both land use and soil management practices (Sun *et al.*, 2003). Land use and management practices impact the direction and degree of soil changes. Therefore, the proper land use and management can be useful for improving soil characteristic, reducing soil degradation and in turn achieving the agricultural sustainability (Fayed and Rateb, 2013). Revealing spatial variability of soil quality and its influencing factors are important to improve sustainable land use strategies (Qi *et al.*, 2009). The differences in fertilization, cropping system and farming practices are the main factors influencing soil quality at field scale (Liu *et al.*, 2010).

Primary Salinization

This is natural and involves the accretion of salts due to high salts content in the parent material or groundwater (FAO, 2000). Salts are formed naturally in the soil and water of both humid and arid regions of the world (Molatakgsi, 2005). Salt affected soils could be produced as result of use of naturally salt containing irrigation water, presence of high amount of salt in the soil and high level of ground water table (Mali *et al.*, 2012). Salinity after drought is one of the most frequent environmental tension throughout the world that influences the part of natural farming ecosystems (Ghanbari *et al.*, 2012; Rengasamy, 2005).

Water salinity is cause by various factors such as soil or rock weathering, leaching of salts dissolved from geologic marine sediments, intrusion of seawater and volcano eruption or emission. Poor water transmission properties of sodic sub-soils, low rainfall in dry land areas, transpiration by vegetation and high evaporation during summer has caused accumulation of salts in the root zone soil layers. Soil salinity resulting from rainfall and weathering of rocks are very slow and can take thousands of year before manifestation (Rengasamy, 2005).

Secondary Salinization

This is caused by human factors such as inappropriate irrigation practice with salt rich irrigation water or insufficient drainage, inappropriate application of fertilizer inappropriate irrigation and management systems and industrial and domestic waste water discharged into water bodies. These causes are driven by population growth and socio-economic factors (FAO, 2000). When drainage is inadequate in the soil, salts that were originally evenly distributed throughout the soil profile will be transported to the top layers by irrigation water and left behind as the water evaporates. Excess of salts may accumulate in the surface horizons of soils mainly due to the following reasons: Secondary salinization associated with water logging, high salt content of irrigation water, release of immobilized salts already precipitated in soils, atmospheric salt depositions as in coastal areas, weathering of soil minerals and Use of fertilizers (Bhadauria *et al.*, 2010).

Extent and Distribution of Soil Salinity/Sodicity

In many areas of the world, salinity is one of the principal environmental causes of soil degradation, and consequently, a source of reduction in the biomass (Andre *et al.*, 2004). It is a worldwide environmental problem that mainly occurs in arid and semiarid regions and causes soil degradation (Amal *et al.*, 2014). The problems is mostly widespread in the arid and semi-arid regions where precipitations are insufficient to drain the soluble salts contained in the soil profile and most of the developing countries are located in these two areas but, salt affected soils also occur extensively in sub-humid and humid climates (Ziad *et al.*, 2004). The problem of salt affected soil is a case of global occurrence and it affects developing as well as developed countries. Nearly 20% of worlds cultivated area and nearly half of the worlds irrigated lands are affected by salt affected soils (Mohamed and Tessema, 2013).

Salt affected soils could also found in cold (permafrost), temperate, subtropical, and tropical belts, that is, all the way from the sub-arctic to the equator and for south of it which has a continental or arid climate and where, evapo-transpiration exceeds precipitation either permanently or at least some time of the year. They are therefore extremely wide spread throughout the various continents of the world and occupy extensive areas globally (Gupta and Abrol, 1990). In some countries, salinization may even threaten the national economy. This is particularly the problem of Argentina, Egypt, India, Iraq, Pakistan, Syria and Iran (Rhoades and Corwin, 1990).

Classes of Salt Affected Soils

Soils having soluble salts in solution and/or Na⁺ ions on exchange sites exceeding certain limits that can adversely affect soil plant health are called salt affected soils. Salt affected soils are classified in to three categories namely saline, saline-sodic and sodic (USSLS, 1954).

Table 1. Summary of classification of salt affected soils based on their chemical properties.

| Classes of Salt affected Soils | Electrical conductivity (ECe) at 25 °C (dS/m) | Exchange percentage (ESP) | Sodium adsorption ratio (SAR) | Reaction (pH value) |
|--------------------------------|---|---------------------------|-------------------------------|---------------------|
| Saline soil | > 4 | < 15 | < 13 | <8.5 |
| Saline sodic soil | > 4 | > 15 | > 13 | <8.5 |
| Sodic (alkali) soil | < 4 | > 15 | > 13 | 8.5-10 |
| Non-saline non-sodic | < 4 | < 15 | < 13 | About neutral |

Source : USSLS, 1954

The Soil Survey uses the criteria as given by USSLS, (1954) for classification of salt-affected soils by taking into consideration the pH, ECe, SAR and ESP.

Saline Soils

Saline soils are soils containing excessive quantities of soluble salts as to interfere with the growth of most crop

plants. The yield of most crop plants is reduced at this ECe, though many crops exhibit yield reduction at lower ECes (Jamil *et al.*, 2011). Saline soils are typically well-structured, permeable soils and hence they are non-sodic soils containing sufficient quantity of soluble salts to adversely affect the growth of most crop plants (FAO, 1998). The chemical characteristics of soils classed as saline are mainly determined by the kinds and amounts of salts present. The amount of soluble salts present controls the osmotic pressure of the soil solution. The relative amounts of calcium and magnesium present in the soil solution and on the exchange complex may vary considerably. Soluble and exchangeable potassium are ordinarily minor constituents, but occasionally they may also be the major constituents (USSLS, 1954).

Soil salinity refers to surface or near-surface accumulation of salts. It is a worldwide environmental problem that mainly occurs in arid and semiarid regions and causes soil degradation (Amalet *et al.*, 2014). Soil salinity is also a serious problem in areas where groundwater of high salt content is used for irrigation. Saline soils usually contain sufficient soluble salts that adversely affect the growth of most crops. The soluble salts are mainly chlorides and sulphates of sodium, calcium and magnesium. Soil salinity may occur under irrigated and non-irrigated conditions. When salinity occurs under irrigated and non-irrigated conditions it is termed irrigated land salinity and dry-land salinity, respectively (FAO, 1988).

Sodic Soils

Sodic soils are soils containing excessive quantities of exchangeable sodium in their exchange complex as to interfere with the growth of most crop plants. Generally, a sodic soil is defined as a non-saline soil which contains sufficient amount of exchangeable Na to adversely affect crop production and soil physical properties through its effect on soil structure (FAO, 1998). Sodic soils are poorly-structured soils with dispersed clays in the top soil and characterized by dispersion of colloidal clays leading to low permeability and infiltration rates, poor aeration, surface soil crusting and difficult to till and for plant roots to penetrate through. The pH of sodic soils is often greater than 8.5 due to "alkali hydrolysis reaction of sodium" and lack of insoluble carbonates (calcium carbonate) to buffer the pH (USSLS, 1954; Brady and Weil, 2002).

Sodicity problems manifest at higher relative Na⁺ concentration and lead to degradation of soil structure. Sodicity problems are usually inherent with salinity in irrigated clayey soils having significant sodium content. Sodicity is common also in soils irrigated with water containing considerable bicarbonate concentrations. High levels of sodium in irrigation water typically result in an increase of soil sodium levels, which affect soil structural stability, infiltration rates, drainage rates, and crop growth potential (USSLS, 1954). High sodium contents result in destruction of the soil structure which, due to a lack of oxygen, becomes incapable of assuring plant growth and animal life (Wichern *et al.*, 2006).

Saline- Sodic Soils

Saline sodic soils are containing excessive quantities of both soluble salts and exchangeable sodium as to interfere with the growth and production of most crop plants. Unlike sodic soils, saline sodic soils are typically well-structured and permeable soils. In fact, the properties of saline sodic soils are much like those of saline soils (USSLS, 1954; FAO, 1999). Saline-sodic soils form as a result of the combined processes of salinization and alkalization. As long as excess salts are present, the appearance and properties of these soils are generally similar to those of saline soils. Under conditions of excess salts, the pH readings are seldom higher than 8.5 and the particles remain flocculated (USSLS, 1954).

Impacts of Soil Salinity/Sodicity on Soil-Water Relations

Agricultural crops exhibit a spectrum of responses under salt stress. Salinity not only decreases the agricultural production of most crops, but also, affects soil physicochemical properties, and ecological balance of the area. The impacts of salinity include low agricultural productivity by decreasing the capacity of the plant to uptake water and causing soil erosions and hence, results low economic returns. Salinity is a severe problem in many regions of the world which changes physico-chemical characteristics of soil and hindered the uptake of water by plants (Hu and Schmidhalter, 2002).

Soil water salinity can affect soil physical properties by causing fine particles to bind together into aggregates (flocculation) and is beneficial in terms of soil aeration, root penetration, and root growth. Although increasing soil solution salinity has a positive effect on soil aggregation and stabilization, at high levels salinity can have negative impact and potentially lethal effects on plants. As a result, salinity cannot be increased to maintain soil structure without considering potential impacts on plant health. On the other hand, sodium has the opposite effect of salinity on soils. The primary physical processes associated with high sodium concentrations are soil dispersion and clay platelet and aggregate swelling. The forces that bind clay particles together are disrupted when too many large sodium ions come between them and then clay particles expand, causing swelling and soil dispersion. The three main problems caused by sodium-induced dispersion are reduced infiltration, reduced hydraulic conductivity and surface crusting (Hanson *et al.*, 1999).

Soil dispersion hardens the soil and blocks water infiltration which makes it difficult for plants to establish and grow. The major implications associated with decreased infiltration due to sodium-induced dispersion include reduced plant available water and increased runoff and soil erosion. Soil dispersion not only reduces the amount of water entering the soil, but it also affects the hydraulic conductivity of the soil (Pearson, 2003). Hydraulic conductivity refers to the rate at which water flows through the soil. For instance, soils with well-defined structure will contain a large number of macro-pores, cracks, and fissures which allow for relatively rapid flow of water through the soil. When sodium-induced soil dispersion causes loss of soil structure, the hydraulic conductivity is also reduced. If the water cannot pass through the soil, then the upper layer can become swollen and water logged. This results in anaerobic soils which can reduce or prevent plant growth and decrease organic matter decomposition rates. The decrease in decomposition causes soils to become infertile, black alkali soils (Hanson *et al.*, 1999; Pearson, 2003).

Dispersed clay particles within the soil solution can clog soil pores when the particles settle out of solution. Additionally, when dispersed particles settle, they may form a nearly structure less cement-like soil. This pore plugging and cement-like structure make it difficult for plants to get established and grow. It also impedes water flow and water infiltration into the soil (Ayers and Westcot, 1976). The disruption of soil hydraulic properties has two main consequences. First, there is less water infiltrating into the soil, and therefore less plant available water, particularly at deeper depths and secondly, runoff, and therefore water loss and soil erosion, may be enhanced (Bauder and Brock, 2001).

The effects of E_c and SAR on soil physical properties and infiltration rate of the soil can also be assessed through the potential impacts of various irrigation water qualities on infiltration rates (Hanson *et al.*, 1999). Accordingly, the relationship between salinity, sodicity and infiltration rate is a severe problem if the irrigation water has low salinity and high sodicity (Figure 1). At SAR = 15, a severe reduction in infiltration will occur at an EC = 1 dS/m. An E_c of 2.5 or less results in a slight to moderate reduction in infiltration. With an E_c greater than 2.5, there will likely not be a reduction in infiltration.

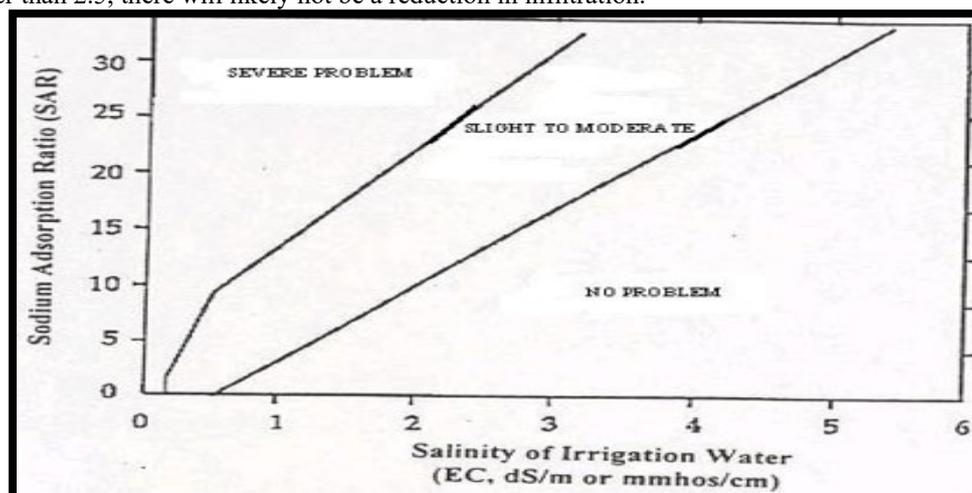


Figure 1. Potential for reduction in infiltration rates resulting from various combinations of E_c and SAR of applied water (Hanson *et al.*, 1999).

Salts that contribute to salinity, such as calcium and magnesium, do not have this effect because they are smaller and tend to cluster closer to clay particles (Figure 2). Calcium and magnesium will generally keep soil flocculated because they compete for the same spaces as sodium to bind to clay particles. Increased amounts of calcium and magnesium can reduce the amount of sodium-induced dispersion (Hanson *et al.*, 1999).

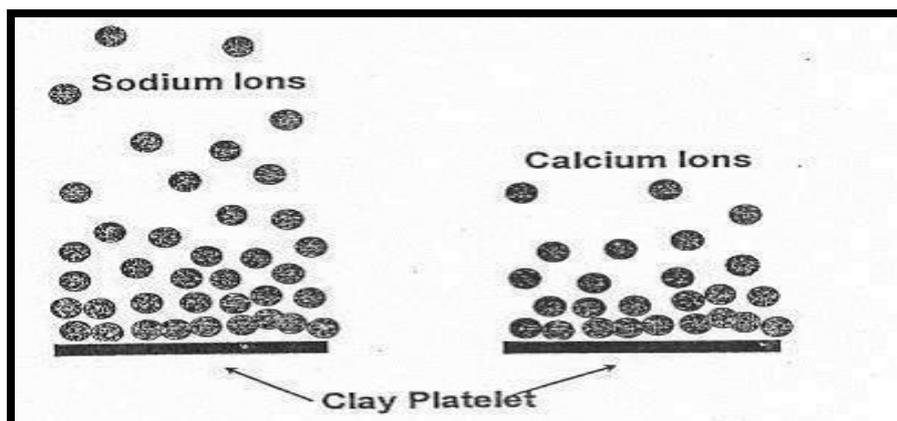


Figure 2. Behavior of sodium and calcium attached to clay particles (Hanson *et al.*, 1999)

Impacts of Soil Salinity/Sodicity on Soil Microbial Population

The microbial communities of the soil perform a fundamental role in cycling nutrients, in the volume of organic matter in the soil and in maintaining plant productivity. Thus, it is important to understand the microbial response to environmental stress, such as high concentrations of heavy metals of salts, fire and the water content of the soil. Stress can be detrimental for sensitive microorganisms and decrease the activity of surviving cells, due to the metabolic load imposed by the need for stress tolerance mechanisms. In a dry hot climate, the low humidity and soil salinity are the most stressful factors for the soil microbial flora (Ibekwe *et al.*, 2010; Chowdhury *et al.*, 2011).

According to Jiang *et al.* (2007) who carried out a research on naturally saline soils, the detrimental influence of salinity on the microbial soil communities and their activities and reported that the effect is always more pronounced in the rhizosphere due to increase in water absorption by the plants for transpiration. The simple explanation for this is that life in high salt concentrations has a high bio-energetic taxation, since the microorganisms need to maintain osmotic equilibrium between the cytoplasm and the surrounding. As a result, sufficient energy for osmo-adaptation is required. The composition of the microbial community may be affected by salinity (Chowdhury *et al.*, 2011) since the microbial genotypes differ in their tolerance of a low osmotic potential. In fungi, a low osmotic potential decreases spore germination and the growth of hyphae and changes the morphology and gene expression resulting in the formation of spores with thick walls (Jiang *et al.*, 2007).

Physical and chemical properties of salt affected soils varies from season to season (Mali *et al.*, 2012). This seasonal variation of physico-chemical properties of salt affected soils, result shows that salinity fluctuates between 0.76 to 1.24 dSm⁻¹ and salinity in the top layers of soil tended increase due to high rate of evaporation during summer month, whereas the leaching taken place during monsoon. Moreover, Mali *et al.* (2012) concluded that Variation in physico-chemical, characteristics of salt affected soil collected from the study site indicated high salinity and dominance of Na⁺ and Cl⁻ resulted in high SAR value in summer as compared to other seasons. This suggests that it would be better to sow seeds or cultivate plants in such a soil when salinity of study site is minimum that is in monsoon. It is recommended that farmer should avoid over irrigation, stop using chemical fertilizer, use drip irrigation system and apply biological fertilizer.

Table 1. Seasonal variation in Physico-chemical characteristics of salt affected soils

| S/N | Some selected physico-chemical properties of soils | Monsoon Season | Winter Season | Summer Season |
|-----|--|----------------|---------------|---------------|
| 1 | Ph | 6.98 | 8.25 | 8.42 |
| 2 | ECe(dsm ⁻¹) | 0.76 | 1.05 | 1.24 |
| 3 | ESP | 68.72 | 58.32 | 41.37 |
| 4 | RSC | 5.35 | 6.00 | 4.5 |
| 5 | SAR | 4.48 | 3.61 | 7.66 |
| 6 | Ca ⁺⁺ (meq ⁻¹) | 0.85 | 1.25 | 0.95 |
| 7 | Mg ⁺⁺ (meq ⁻¹) | 1.2 | 2.05 | 6.65 |
| 8 | Na ⁺ (meq ⁻¹) | 4.11 | 4.48 | 4.61 |
| 9 | K ⁺ (meq ⁻¹) | 6.56 | 7.91 | 11.7 |
| 10 | Cl ⁻ (meq ⁻¹) | 3.8 | 5.5 | 5.8 |

Source : Mali *et al.* 2012.

In salt-affected soil pH inhibits water and nutrient uptake although there is sufficient quantity of water and nutrient in the soil system. Accordingly, absorption of nutrient by the plant and growth of plants depend upon the pH of their habitat and the recorded pH of saline soil supporting succulent halophytes (a plant adapted to grow in saline environment) fluctuates between 7.5 to 8.2 (mali *et al.*, 2012).

Crop varieties differ in their response to various biotic and abiotic stresses. Excessive salt concentrations decrease water potential and thus, result in reduced water availability to the plant. Under such situations plants often show wilting due to physiological drought. Poor germination, seedling emergence and establishments under saline conditions lead to poor crop productivity (Agnihotri and Singh, 2006). When SAR is 15 or more, Na^+ is responsible for changing physico-chemical properties of soil and hamper the uptake of water by plants (Sajirani *et al.*, 2011).

Excess soluble salts in the root zone restrict plant roots from withdrawing water from the surrounding soil and effectively reducing the plant available water. Basically, water is both held tighter to the soil in saline environments and is also less available for plant uptake due to osmotic forces. This leads to reduced water uptake and increased plant stress (Bauder and Brock, 2001; Hanson *et al.*, 1999). For example, when plant growth is compared in two identical soils with the same moisture levels, one soil receiving salty water and the other receiving salt-free water, plants are able to use more water from the soil receiving salt-free water. Although the water is not held tighter to the soil in saline environments, the presence of salt in the water causes plants to exert more energy extracting water from the soil. The main point is that excess salinity in soil water can decrease plant available water and cause plant stress (Bauder and Brock, 2001).

Soil water salinity is dependent on soil type, climate, water use and irrigation routines. For example, immediately after the soil is irrigated, plant available water is at its highest and soil water salinity is at its lowest. However, as plants use soil water, the remaining water is held tighter to the soil and becomes progressively more difficult for plants to obtain. As the water is taken up by plants through transpiration or lost to the atmosphere by evaporation, soil water salinity increases because salts become more concentrated in the remaining soil water. Thus, evapotranspiration (ET) between irrigation periods can further increase salinity. This effect becomes most pronounced during periods of high evapotranspiration demand, such as hot sunny summer days and during the peak of the growing season (Hanson *et al.*, 1999).

According to Ayers and Westcot (1976), when the Electrical Conductivity of the soil water ($\text{EC}_{\text{sw}} = 30 \text{ dSm}^{-1}$ ($=30 \text{ mmhoscm}^{-1}$) and the soil water content is at 27%, plants will be at their wilting point, i.e. -15 bars osmotic potential. In contrast, at an $\text{EC}_{\text{sw}} < 2 \text{ dSm}^{-1}$, plants will not reach their wilting point until the soil is at approximately 15% soil water content. Another way of looking at this is that if a crop has a constant ET demand of 6 mmday^{-1} the soil will have a $27\frac{1}{2}$ day supply of available water (water the crop can utilize) at a soil water $\text{EC}_{\text{sw}} = 3 \text{ dSm}^{-1}$, a 20 day supply of available water at $\text{EC}_{\text{sw}} = 15 \text{ dSm}^{-1}$ and a 10 day supply of available water at $\text{EC}_{\text{sw}} = 30 \text{ dSm}^{-1}$.

Impacts of Soil Salinity/Sodicity on Plant Growth

Salinity is of concern because of its deleterious effect on plant growth, nutritional balance, and plant and flower marketable quality, including visual injury, flower distortion, and reduced stem length. Plant growth is detrimentally affected by salinity as a result of the disruption of certain physiological processes that lead to reductions in yield and/or quality. Growth, yield, and quality reduction may occur through a decrease in the ability of plants to take up water from the soil solution and the destruction of soil structure. In addition, toxicity resulting from excessive concentration of certain ions, principally Na^+ , Ca^{2+} , Mg^{2+} , Cl^- , SO_4^{2-} , and HCO_3^- as well as nutritional imbalances (Barrett, 2003). The saline growth medium causes many adverse effects on plant growth, due to a low osmotic potential of soil solution (osmotic stress), specific ion effects (salt stress), nutritional imbalances, or a combination of these factors. All these factors cause adverse effects on plant growth and development at physiological and biochemical levels and at the molecular level (Ashraf, 2004).

Phosphorus (P) is an essential macronutrient, being required by plants in relatively large quantity i.e. ~0.2 to 0.8%. The P plays an important role in early vegetative growth stages, because it promotes tillering and root development. However, P deficiency is a well-known nutrient constraint on salt-affected soils. Simply adding P fertilizer at normal rates in these soils may not result in optimal yield and crop quality (Mahmood *et al.*, 2013). The availability of P to plants for uptake and utilization is messed up in alkaline and calcareous soils due to formation of poorly soluble calcium phosphate raw materials and hence fixation and precipitation of applied P will occur. The resulting effect of low P solubility in calcareous alkaline soils is relatively poor in P fertilizer efficiency. The high concentration of calcium in the soil results in precipitation of insoluble calcium phosphate compounds for a short time and decreases P availability. Plants grown on such soils can be stunted with shortened internodes and poor root system due to P deficiency (Mohamed and Tessema, 2013).

Salinity effects are the results of complex interactions among morphological, physiological, and biochemical processes including seed germination, plant growth, and water and nutrient uptake (Akbarimoghaddam *et al.*, 2011). Salinity affects almost all aspects of plant development including: germination, vegetative growth and reproductive development. Soil salinity imposes ion toxicity, osmotic stress, nutrient (N, Ca, K, P, Fe, Zn) deficiency and oxidative stress on plants, and thus limits water uptake from soil. Soil salinity significantly reduces plant phosphorus (P) uptake because phosphate ions precipitate with Ca ions (Bano and Fatima, 2009). Salinity stress affects the grain yield, vegetative growth and number of capsules. In case of germination percentage of seeds,

germination percentage decreases with increasing in NaCl concentrations (Sajirani *et al.*, 2011).

Some elements, such as sodium, chlorine, and boron, have specific toxic effects on plants. Excessive accumulation of sodium in cell walls can rapidly lead to osmotic stress and cell death (Munns, 2002). Plants sensitive to these elements may be affected at relatively low salt concentrations if the soil contains enough of the toxic element. Because many salts are also plant nutrients, high salt levels in the soil can upset the nutrient balance in the plant or interfere with the uptake of some nutrients (Blaylock *et al.*, 1994). Salinity also affects photosynthesis mainly through a reduction in leaf area, chlorophyll content and stomata conductance. Moreover, it is also adversely affects reproductive development by inhabiting stamen filament elongation, enhancing programmed cell death in some tissue types, ovule abortion and senescence of fertilized embryos (Netondo *et al.*, 2004).

In order to assess the tolerance of plants to salinity stress, growth or survival of the plant is measured because it integrates the up or down-regulation of many physiological mechanisms occurring within the plant. Osmotic balance is essential for plants growing in saline medium. Failure of this balance results in loss of turgidity, cell dehydration and ultimately, death of cells. On the other hand, adverse effects of salinity on plant growth may also result from impairment of the supply of photosynthetic assimilates or hormones to the growing tissues (Ashraf, 2004). Ion toxicity is the result of replacement of K^+ by Na^+ in biochemical reactions, and Na^+ and Cl^- induced conformational changes in proteins. For several enzymes, K^+ acts as co-factor and cannot be substituted by Na^+ . Ion toxicity and osmotic stress cause metabolic imbalance, which in turn leads to oxidative stress (Chinnusamy *et al.*, 2006).

The adverse effects of salinity on plant development are more profound during the reproductive phase. Wheat plants stressed at 100–175 mMNaCl showed a significant reduction in spikelet's per spike, delayed spike emergence and reduced fertility, which results in poor grain yields. However, Na^+ and Cl^- concentrations in the shoot apex of these wheat plants were below 50 and 30 mM, respectively, which is too low to limit metabolic reactions (Munns and Rawson, 1999). Hence, the adverse effects of salinity may be attributed to the salt-stress effect on the cell cycle and differentiation. Recent reports also show that salinity adversely affects plant growth and development, hindering seed germination, seedling growth, enzyme activity (Seekin *et al.*, 2009), DNA, RNA, protein synthesis and mitosis (Tabur and Demir, 2010; Javid *et al.*, 2011).

Conclusion

The majority of the population living in the arid and semi-arid areas mainly depend on agriculture for subsistence. Soil salinization and alkalization are the major constraints affecting the cereal crop production in arid and semi-arid areas. Integrated catchment management in dry land areas are often neglected while expanding agricultural development. Productivity of soils is increasingly affected by highly unfavorable drainage conditions, improper farming and inappropriate irrigation practices.

Widespread of salinization/alkalization problems in dry land areas negatively affected soil–water properties and crop productivity. Impacts of salinity on plant are complex interactions among morphological, physiological, and biochemical processes including seed germination, plant growth, and water and nutrient uptake. Therefore, as soil is the basis of all terrestrial ecosystems, degraded soil means lower fertility, reduced biodiversity and reduced human welfare and hence, protecting soils from such degradation is extremely important to providing safe and sound habitat for the future generations.

References

- Agnihotri, K. and Singh, P. 2006. Impact of canal irrigation in arid region. *Annual Report of Karnal, India* , 173-175.
- Akbarimoghaddam, H., Galavi, M., Ghanbari, A., Panjehkeh, N. 2011. Salinity effects on seed germination and seedling growth of wheat cultivars. *Journal of soil Science*, 9 (1): 43-50.
- Akram, M. Ashraf M., Ahmad, R., Rafiq, M., Ahmad, I. and Iqbal, J. 2010. Allometry and yield components of maize (*Zea Mays* L) hybrids to various potassium levels under saline conditions. *Archives of Biological Science Belgrade*, 62(4): 1053-1061.
- Amal, A., Lalit, K. and Priyakant, S. 2014. Mapping and Modelling Spatial Variation in Soil Salinity in the Al Hassa Oasis Based on Remote Sensing Indicators and Regression Techniques. *Remote Sensing*, 6(2), 1137-1157.
- Andre, D., Jose, T., Joaquim, F., Claudivan, F. Jose, V. and Gomes, F . 2004. Effects of salt stress on plant growth, stomatal response and solute accumulation of different maize genotypes. *Brazil Journal of Plant Physiology*, 16(1): 31-38.
- Ashraf, M. 2004. Some important physiological selection criteria for salt tolerance in plants. *Flora* 19: 361–376.
- Awulachew, S., Yilma, A., Loulseged, M., Loiskandl, W., Ayana, M. and Alamirew, T . 2007. *Water Resources and Irrigation Development in Ethiopia*. Working Paper 123, Colombo, Sri Lanka, International Water Management Institute, 78.

- Ayers, R. and Westcot, D. 1976. *Water Quality for Agriculture*. FAO, Irrigation and Drainage Paper No. 29.
- Bano, A., Fatima, M. 2009. Salt tolerance in *Zea mays* (L.) following inoculation with *Rhizobium* and *Pseudomonas*. *Biological Fertility of Soils* 45(7): 405–413.
- Barrett, G. 2003. The interaction between waterlogging and salinity in higher plants: Causes, consequences and implications. *Journal of Plant Science*, 25(3):35–54.
- Bauder, J. and Brock, T. 2001. Irrigation water quality, soil amendment, and crop effects on sodium leaching. *Arid Land Research and Management*. 15(8):101-113.
- Bhadoria, S., Sengar, M., Dheeraj, M., Chatar, Singh, D. and Kushwah, B. 2010. Sustainable Land Use Planning Through Utilization of Alkaline Waste land by biotechnological Intervention. *American-Eurasian Journal of Agriculture and Environmental Science*, 9 (3): 325-337.
- Blaylock, A. 1994. *Soil salinity, salt tolerance and growth potential of horticultural and landscape plants*. University of Wyoming, Department of Plant, Soil and Insect Sciences, College of Agriculture, Laramie, Wyoming.
- Bot, A., Nachtergaele, F. and Young, A. 2000. Land resource potential and constraints at regional and country levels. FAO Rome, *World Soil Resources Report* 90, 114.
- Brady, N. and Weil, R. 2002. *The Nature and Properties of Soils. 13th ed.* Macmillan Publishing Company, Inc. USA.
- CASL (Community Adaptation and Sustainable Livelihoods). 2006. *Arid and Semi-arid lands: characteristics and importance*. University of Dodoma, Dodoma, Tanzania.
- Chinnusamy, V., Zhu, J., Zhu, J. 2006. Gene regulation during cold acclimation in plants. *Physiology of Plant*. 126 (1): 52–61.
- Chowdhury, N., Marschner, P. and Burns, G. 2011. Soil microbial activity and community composition: impact of changes in matric and osmotic potential. *Soil Biology and Biochemistry*, 6(43): 1229-1236.
- FAO (Food and Agricultural Organization). 1988. *Salt Affected Soils and Their Management*. FAO Soils Bulletin 39, Rome, Italy.
- FAO (Food and Agricultural Organization). 1999. *Soil salinity assessment methods and interpretation of electrical conductivity measurements*. US salinity laboratory united states department of agriculture, riverside, California, USA.
- FAO (Food and Agricultural Organization). 2000. Global network on integrated soil management for sustainable use of salt affected soils, Available from: www.fao.org/agl. Accessed on 13/03/2016.
- FAO (Food and Agricultural Organization). 2009. Advanced in the assessment and monitoring of salinization and status of bio-saline agriculture, *World soil resource report of an expert*, consultation held in Dubai, UAE, 26-29.
- FentawAbegaze, KidaneGiorgis, Abebe Fanta, HelufGebrekidan, WondimadegneChekol, HibstuAzeze, AsegidAyalew, Messele Fisseha and Mohammed Bedel. 2006. *Report of the National Task Force on Assessment of Salt Affected Soils and Recommendations on Management Options for Sustainable Utilization*. EIAR.
- Fayed, I. and Rateb, K. 2013. Long-Term Cropping System Impacts on Some Physical and Chemical Properties and Fertility Status in Alluvial Soils of Egypt. *Soil, Water and Environment*, 58(1): 9-18.
- Ghanbari, M., Bahmanyar, S., Gilani, F. and Raiesi, M. 2012. The effect of different levels of saline irrigation water and some amendments on microbial respiration, and acid and alkaline phosphatase activities in the rhizosphere soil during vegetative growth of Soybean. *Journal of Water and Soil Conservation*, 19(3):63-76.
- Gupta, R. and Abrol, R. 1990. Salt Affected Soils, Their reclamation and management for crop production. *Advances in Soil Science*, 26(11) : 223-288.
- HailayTsige, Tadelle G/sellasi and TekalignMamo. 2000. Assessment of salinity/sodicity problems in Abaya state farm, southern rift valley of Ethiopia. *Ethiopian Journal of Natural Resources*, 2 (2): 151-163.
- Hanson, B., Grattan, S. and Fulton, A. 1999. *Agricultural Salinity and Drainage*. University of California Irrigation Program. University of California, Davis.
- Horney, R., Taylor B., Munk, D. Roberts, B., Lesch, S. and Richard, E. 2005. *Computer and Electronics in Agriculture*, 46, 379-397.
- Hu, Y. and Schmidhalter, U. 2002. *Limitation of salt stress to plant growth*. Elstner, C.F. Plant Toxicology. Marcel Dekker Inc., New York, 91–224.
- Ibekwe, A., Poss, J., Grattan, S., Grieve, C. and Suarez, D. 2010. Bacterial diversity in cucumber (*Cucumis sativus*) rhizosphere in response to salinity, soil pH, and boron. *Soil Biology and Biochemistry*, 4(42): 567-575.
- IIRR (International Institute of Rural Re-construction). 2002. *Managing Dryland Resources- An extension manual for Eastern and Southern African International Institute of Rural Re-construction*. Nairobi, Kenya.
- Jamil, A., Riaz, S., Ashraf, M., Foolad, R. 2011. Gene expression profiling of plants under salt stress: A review. *Journal of Plant Science*, 30 (5): 435–458.
- Javid, M., Sorooshzadeh, A., Moradi, F., Sanavy, Seyed, A. and Allahdadi, I. 2011. The role of phyto-hormones

- in alleviating salt stress in crop plants. *American Journal of Crop Science*, 5 (6): 726–734.
- Jiang, H., Dong, H., Yu, B., Liu, X., Li, Y., Ji, S. and Zhang, C. 2007. Microbial response to salinity change in Lake Chaka, a hyper-saline lake on Tibetan plateau. *Environmental microbiology*, 9 (10): 2603-2621.
- Khouri. 2003. Sustainable Development and Management of Water Resources in the Arab Region. *Development of Water Science*, 50(13): 199–220.
- Koohafkan, P., and Stewart, B. 2008. *Water and Cereals in Dry lands*. FAO, Rome.
- Konrad, M. 2001. *Principles of Plant Nutrition*. 5th Edition, Justus Liebig University, Giessen, Germany School of Biology.
- Liu, E., Yan, C., Mei, R., Bing, S., Ding, L., Liu, Q., Liu, S., and Fan, T. 2010. Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. *Geoderma*, 15(8): 173-180.
- Mahmood, I., Ali, M., Aslam, A., Shahzad, B., Sultan, T. and Hussain, F. 2013. Phosphorus availability in different salt-affected soils as influenced by crop residue incorporation. *International Journal of Agriculture and Biology*, 15(29): 472–478.
- Mali, B., Thengal, S. and Pate, N. 2012. Physico - chemical characteristics of salt affected soil from Barhanpur, M.S., India. *Annals of Biological Research*, 3 (8):4091-4093.
- Mason, C. 2002. *Biology of fresh water pollution. 4th edition*. Pearson Prentice Hall. Amazon New York Series, Great Britain.
- Mohamed Seid and Tessema Genew. 2013. Evaluation of soil and water salinity for irrigation in North-eastern Ethiopia: Case study of Fursa small scale irrigation in Awash River Basin. *African Journal of Environmental Science*, DOI:10.5897/AJEST2013.1464.
- Molatakgosi, G. 2005. *Impact of in field irrigation management by Botswana cabbage farmers on soil salinity*. Cranfield University, UK.
- Munns, R. 2002. Comparative physiology of salt and water stress. *Plant Cell Environment*. 25(10): 239–250.
- Munns, R. and Rawson, H. 1999. Effect of salinity on salt accumulation and reproductive development in the apical meristem of wheat and barley. *Australian Journal of Plant Physiology*, 26(4): 459–464.
- Netondo, G., Onyango, J. and Beck, E. 2004. Sorghum and salinity: Gas exchange and chlorophyll fluorescence under salt stress. *Journal of Crop Science*, 44(7): 806–811.
- Pearson, E. 2003. *The Basics of Salinity and Sodicty Effects on Soil Physical Properties. USA*. Department of Land Resources and Environmental Sciences, Montana University.
- Qi, B., Darilek, J., Huang, B., Zhao, Y., and Sun, W. 2009. Evaluating soil quality indices in an agricultural region of Jiangsu Province of China. *Geoderma*, 149(3-4): 325-334
- Rengasamy, P. 2002. Transient salinity and subsoil constraints to dry land farming in Australian sodic soils: An overview. *Australian Journal of Agriculture*, 42(13): 351–361.
- Rengasamy, P. 2005. *World salinisation with emphasis on Australia*. Compiled Bio-chemistry and Physics, Australia, 337-348.
- Rhoades, J. and Corwin, D. 1990. Soil electrical conductivity: effects of soil properties and application to soil salinity appraisal. *Communication in Soil Science and Plant Analyses*, 21(9): 836-860.
- Sajirani, E., Shakouri, M. and Mafakherig, S. 2011. Effect of salinity on plants. *Annals of Biological Research*, 2(6): 414-416.
- Seckin, B., Sekmen, A., Turkan, I. 2009. An enhancing effect of exogenous mannitol on the antioxidant enzyme activities in roots of wheat under salt stress. *Journal of Plant Growth Regulation*, 28(3): 12–20.
- Shahbaz, M., Ashraf, M. 2013. Improving salinity tolerance in cereals. *Review of Plant Science*, 32(19): 237–249.
- Squires, V. and Glenn, E. 2004. *Salinization, Desertification, and Soil erosion :The Role of Food, Agriculture, Forestry and Fisheries in Human Nutrition*. Oxford, UK.
- Sun, B., Zhou, S. and Zhao, Q. 2003. Evaluation of spatial and temporal changes of soil quality based on geo-statistical analysis in sub-tropical China. *Geoderma*, 115(6): 85-99.
- Tabur, S. and Demir, K. 2010. Role of some growth regulators on cytogenetic activity of barley under salt stress. *Plant Growth Regulation*, 60(11): 99–104.
- USSSL (United State Salinity Laboratory Staff). 1954. *Diagnosis and improvement of saline and alkali soils*. Agriculture Hand book 60, USDA, Washington, D.C.
- Wichern, J., Wichern, F. and Joergensen, R. 2006. Impact of salinity on soil microbial communities and the decomposition of maize in acidic soils. *Annals of Biological Research*, 137(8): 0016-7061.
- Yonas, Y. 2001. *Managing fragile ecosystem, combating desertification and drought*. Ethiopian Civil Society Preparation. The Forum for Environment. Heinrich Boll Foundation, Addis Ababa, Ethiopia.
- Yonas Girma. 2005. Appraisal, Spatial structure and Mapping of soil salinity and Irrigation water quality of Yellen Jeweha areas in North Shewa zone of the Amhara region. *MSc Thesis, Alemaya University*.
- Ziad, A., Ferdinand, B. and Ramata, M. 2004. Modeling the Back scattering Coefficient of Salt-affected soils: Application to Wadi El-natural bottom, Egypt, Canada. *Zone 3*: 727.