

Soil Salinity Causes, Effects, and Its Managements

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ABSTRACT

Salt affected soil is one of the formidable environmental variables affecting crop plant output, since different crop plants are susceptible to various salt concentrations levels as the results of low ground water levels, and inappropriate irrigation practices. Because there is not enough yearly rainfall in drought regions of the worldwide, an amount of soil salinity could be accumulated from plant roots can boost the soil salinity. In order to overcome the soil salinity problems, numerous adaptations, mitigation policies, and strategic strategies are needed. It can be mitigated with the use of appropriate irrigation, leaching, better crop varieties that are tolerant of salt, and beneficial soil microorganisms. Soil microbes facilitate the dissociation of organic matter, increase nutrient availability, improve plant genetic diversity, plant growth promoting hormones, and ultimately enhance crop productivity, environmental stability, ecosystem service, and food security.

Keywords: Leaching; Microbes; Salinity; Salt-Tolerant Crop

Introduction

Soil salinity is primarily the common agriculture problem and more aggravated in the lowland and especially in the desert areas, where low precipitation to evaporation ratio is too low. Soil salinity is also the main abiotic risks to agricultural land as a worldwide, which adversely affecting crop production and productivity (Zhao, et al. [1]). Salt concentration is naturally high in arid/semi-arid regions, in which precipitation may not be sufficient for leaching and remove the accumulated salt from plant root zone. Due to poor management practices and environmental stresses such drought, soil salinity, acidity, erosion, flooding, and topographic location, agricultural land experiences a variety of environmental challenges that cause the quality of the soil to change over time (Kaya, et al. [2]). According to Shahbaz and Ashraf [3] salt affected soil is the serious agricultural problem, which mainly triggered as the result of improper irrigation, which in turns adversely affect crops productivity and quality. Currently, over 800 million hectares or more than 6% of the total worldwide coverage areas are damaged by soil salinity and/or soil sodicity of which, around 15 - 20 % of all irrigated land affected by the saline soil (Safdar, et al. [4]).

Since the agriculture sector generates 40% of the GDP, 80% of all jobs, and 70% of export revenue, Ethiopia is highly dependent on agricultural activities (Yohannes, et al. [5]). The issue of salinity is the tremendous problems, which totally affecting about 11 million hectares of land coverage in Ethiopia and considered as the highest area in the rest African country (Fantaw [6]). Due to the expansion of the agriculture sector over the last ten years, it become possible to produce about 27 million tons of crop productivities, which used to assure the nations' food self-sufficient. Strong government policies and strategies that set aside more than 15% of the overall budget for the growth of the agriculture sector were the cause of this agrarian activity (Mekonnen [7]). The degree of salinity varies geographically, but it is most severe in the low lands of the some areas like arid, semi-arid, and desert lowlands, such as the desert of Afar and, Somali regions, as well as the lowland and arid areas of others regions (Gedamu [8]).

About 47% of the nation's 113 million hectares are made up of the lowlands and arid zonal areas of the country, where crop production and productivities are extremely susceptible to soil salinity (Adhanom [9]). In addition to low agricultural productivity, salinity can reduce function and diversity of soil microbes, soil fertility, availabil-

ity of plant nutrients, and ultimately reduce the livelihoods of large community. Thus, the main goal of this paper is to review the causes and effects of soil salinity according to Ethiopian soil.

Extent of Soil Salinity in Ethiopia

Generally, it's estimated that salinity is globally affects about 20% and 33% of rain fed cultivation land and of irrigated agricultural land, respectively (Kumar, et al. [10]). Furthermore, soil salinity is yearly increasing at a rate of 10% due to low precipitation to evaporation ratio, disintegration and weathering of salt content rocks, improper irrigation methods, and insufficient drainage systems (Tiwari, et al. [11]). From Ethiopia's total geographical area, around 44 million hectares, or 36%, are vulnerable to salinity; of these, about 12 million hectares have affected by salinity to varied degrees, with the Rift valley suffering the most severe consequences (Auge, et al. [12]). Compare to the worldwide land coverage affected by salinity, Ethiopia was ranked seventh, where agricultural lands, ecosystems, and natural habitats have all suffered as a result of salinity (Gebrehiwot [13]). This has put irrigated areas' productivity in jeopardy because they produce almost 40% of the nation's overall food needs (Meaza, et al. [14]). The salinity range varies throughout different land use land cover and soil types (Qureshi, et al. [15]).

Compared to the land use and soil types found in mountains and gently plateaued regions, like Luvisols, Vertisols, Acrisols, and Nitisols with that of soil types formed in the lowland regions, such as Yermosols, Regosols, and Xerosols, they are contains lower salinity (Hordofa, et al. [16]). Because of the expansion and severity of soil and water salinity, the wide area of lowland regions zones are viewed as marginal conditions for crop development and others agricultural practices (Gebremeskel, et al. [17]). The primarily source of water and soil salinity in arid/semiarid regions is the lower annual precipitation to evaporation ratio, which has a negative impact on agricultural productivity and soil attributes (Nekir, et al. [18]).

Causes of Soil Salinity

Soil salinity is the complex and multifaceted phenomena resulting from a varior causes or combinations of factors that may manifest in different regions of Ethiopia (Haile et al. [19]). Salinity could be brought through different reasons such as improper utilization of agricultural practice, lack /absence of adapted salt tolerant plant species, and improper irrigation techniques, which can be made worse by climate change and other environmental issues including severe droughts (Kohler, et al. [20]). Soil salinity is primarily caused by natural processes, whereas secondary causes are brought on by agricultural methods, improper irrigation, and illogical land use. Primary salinity arises spontaneously in soils and streams where specific geological, hydrological, pedological, and relief processes are linked to the natural processes of salt buildup (Mahmuduzzaman, et al. [21]). Parent materials of those soils include undifferentiated volcanic rocks,

sandstones, lagoon deposits, disintegration of different rocks such as phenolytes and basaltic igneous rocks (Awulachew [22]). Besides to these, different waves, and water pressure formed from oceans and seas, water management practices and climate variables may hasten the salinization process. According to Nouri, et al. [23], evapo-transpiration is play crucial role in the formation of soil salinity as well as sodicity especially in desert regions. The salinity problem created related to coastal areas is another natural salinity a trigger, in which is the intrusion of saline water into rivers and aquifers.

In Asia, for example, coastal rice crops are often susceptible to sea wave as the results of the Indian Ocean (Nia, et al. [24]). The sodium chloride (NaCl) is the dominant and majorities of salts formed or cyclic in the inland accumulated by wind and left behind by precipitation. The amount of rainfall water changes substantially depending on the direction of the fundamental winds and the distance from the coastal areas. Sea water's composition is commonly expressed or represented as g kg⁻¹, which is constant and applicable as worldwide. Seawater has an electrical conductivity (EC) values of seawater is usually 55 dS m⁻¹, whereas that of rainwater has an electrical conductivity of roughly 0.01 dS m⁻¹ (Srivastava, et al. [25]). Soils that are impacted by secondary salt formation are primarily those that result from human activities, such as inappropriate irrigation techniques, a lack of suitable drainage systems that raise the groundwater table quickly, and deforestation that lowers average rainfall and raises surface temperatures (Ramadoss, et al. [26]). By the time improper irrigation system is applied to agricultural land, it causes for an accumulation and buildup of salt content materials in the soil. The gradual accumulated salt in the plant root zone is adversely affected the crop plant and land productivity unless it is timely leached away with proper irrigated water quality (Devkota, et al. [27]). Currently, it was predicted that in large lowland and/or arid areas, around 45 - 50% of mostly an irrigated areas are characterized by soil salinity. It has become more challenging to assess the significance of salinity for future agricultural output due to several recent attempts to measure the degree of secondary salinization caused by humans (Hossain [28]).

Impacts of Soil Salinity on Agricultural Land

Salt buildup and soil organic matter loss could negatively affect the productivity of agricultural lands especially in dry lowland regions (Wichelns, et al. [29]). Salinization processes have a negative effect on the ecosystem services that soil provides to maintain biodiversity and the health of the environment, and also participate in the nitrogen and water cycles (Abebe, et al. [30]). By interfering with the mineralization processes, and microbial function, soil salinization can highly reduce an agricultural production and productivities. The decrease in soil microorganisms' food sources is linked to the loss of biological activity in soils (Asfaw, et al. [31]). Significant ecological stress and substantial threats to the health of the soil and environment are linked to the abandonment of arable soils (Singh [32]). According to

Zewdu, et al. [33], a rise in soil salinity exacerbates the decline of soil ecosystem services and reduces farmer and smallholder income. The final result of low precipitation to evaporation ratios on arid agricultural lands is salinization, which leads to the loss of natural vegetation and trees. When there is a shallow groundwater table, salinization impacts the soil's ability to absorb water, increasing the danger of surface runoff and flooding on several levels (Asmamaw, et al. [34]). Building destruction and damage to highways, dams, wetlands, and agricultural fields can result from flooding (Marschner [35]).

According to Abdulkadir, et al. [36], soil salinization severely reduces agricultural crop productivity and thus has a detrimental impact on food security. Within arid regions, salinity-induced yield losses range from 26% - 43%. This can negatively impact local residents' quality of life and exacerbate the harm caused by climate change and land degradation (Desalegn, et al. [37]). According to Bano and Fatima [38], the annual loss of worldwide revenue from salinizing agricultural land might be as high as from 10 - 12 US\$ billion and about 1 - 2 \$ billion for irrigated land and for non-irrigated land, respectively. As Shahid, et al. [39] stated that the yearly loss of agricultural output is predicted to be 30 - 32 million US\$, while the financial loss resulting from infrastructure deterioration, soil salinization-related land abandonment, and a shortage of water for soil leaching is assessed to be 12 million US\$. According to Agegnehu, et al. [40], the current trends in climate change, which is increasing and accelerated the occurrence of drought; pose a substantial threat to fragile ecosystems in different lowland regions. The processes of salt mobilization and buildup in upper soil horizons are accelerated and dispersed by droughts (Ashraf [41]).

Impact of Salinity on Plants Growth and Performance

The natural interaction between soil and plant morphological characterize, physico-chemical, and biological processes are mainly the causes of soil salinity (Dias, et al. [42]). Soil salinity is most probably negatively impacted every element of crop plant development, including its rate of germination, vigor, and its productivity potential. Agricultural crop plants suffer from different toxicity of elements, osmotic pressure, and nutrients insufficiency, as a result of salt in the soil. This scenario is drastically alleviate the amount of water that staple crop can take from the soil, which in turn improves plant performance (Hernández [43]). Because phosphate ions precipitate with calcium ions to create calcium phosphate, soil salinity drastically decreases the characteristics of availability of phosphorus uptake (Mulugeta, et al. [44]). When soil has sufficient levels of the poisonous element and salinity, crop and vegetation plants those are sensitive to these components may be highly impacted in their morphological and physiological structures. The salt affected in the soil can disturb the flow and order of available certain nutrients hence some salts are also available and uptake by some plants. Additionally, by hinder the growth of plant cell, tissues, make immature ovule and cause for

development of infertile embryos, and inhabiting stamen filament growth, soil salinity can negatively impact an overall growth, performance, and reproductive systems (Netondo, et al. [45]).

Osmotic Effect of Salt

Plant development and performance are negatively impacted by salty soil in a number of ways, including osmotic stress, low soil solution osmotic potential, ion-specific impacts, toxicity, and nutritional imbalances (Ozlu, et al. [46]). According to recent findings, salinity also has a negative impact on the growth and development of plants, since it prevents enzyme activity, seed germination, and seedling growth (Seckin, et al. [47]). Plants absorb water due to a gradient between the soil solution and the cell sap found inside the root cells. Elevated levels of neutral salts in the soil 10 solution tend to close the gap between the internal water potential of plant cells and the soil's external potential (Castillo, et al. [48]). This indicates that salts raise the soil's capacity to hold water (Shabala, et al. [49]). Though the plant is unable to collect it due to the strong negative potential, there may be enough of available soil moisture for plant growth. The plant either doesn't acquire enough water to sustain healthy growth, or it expends too much energy extracting the water, which hinders growth (Yadav, et al. [50]). When there is water stress, the problem gets worse, especially on fine-textured soils where it requires more effort for the plant to extract water at a given soil moisture level (Zhu, et al. [51]).

High soil salinity ($EC > 4 \text{ dS m}^{-1}$) dehydrates plant cells, stunts growth, and may even kill less tolerant plants; tolerant plants, on the other hand, adapt physiologically in a variety of ways whose visual symptoms are all comparable (Zhang [52]). The initial visual signs resemble those of moisture stress resulting from dry weather. According to Heidari [53], plants may be stunted, their leaves may cup, and their general health and color may be impacted. The entire leaf, the leaf edges, and the tips of the leaves become brittle and brown as the symptoms worsen. After planting immature seedlings, these symptoms could appear a few days later or several weeks later. Water deficit in older plants might show up as a quick browning or death of the leaves at the apex of the plant (Asfaw [54]).

Impacts of Salinity on Soil Microorganisms

According to Liu, et al. [55], soil microbes are essential for the breakdown of organic matter, nutrient cycling, improving soil quality, and raising crop productivity. Thus, it is crucial to comprehend how microorganisms function to reduce environmental stressors including excessive salt concentrations of heavy metals, water stress, and to improve the availability of vital nutrients (Yan, et al. [56]). Because of the metabolic burden caused by the requirement for stress tolerance mechanisms, environmental stress can be harmful to sensitive microorganisms and reduce their diversity and ability to survive (Jansson, et al. [57]). Salinity has the greatest detrimental effects on the soil microbial flora and organic matter dissociation rate in dry and semi-arid

soils [Xu, et al. [58]]. In agricultural areas where microbes are present, soil saline stress becomes a serious issue because of the excessive salinity of the soil, which can be made worse by incorrect irrigation techniques and the use of chemical fertilizers [Skudra, et al. [59]]. According to recent studies, salt soils have a major impact on the activities of the soil microbial communities, which in turn affects the plant's ability to branch and elongate, which lowers plant performance [Li, et al. [60]]. The effects of soil salinity are primarily a noteworthy problem in the rhizosphere, where it plays a key role in crop yield, plant transpiration, and agricultural land [Rath, et al. [61]]. The activity of soil microorganisms and their enzymatic activity in the rhizosphere and bulk soil, which are connected to soil properties, are greatly influenced by the high concentration of salt in the soil [Zhang [52]].

Management of Soil Salinity

According to Semiz, et al. [62], there are several methods for controlling soil salinity, including employing microbes to lower element toxicity, applying organic matter (such as manures and residues), choosing and using plants that are tolerant to salt, and access leaching/draining (both surface and subsurface drainage). Improved irrigation techniques, such as the use of sprinkler and drip irrigation to maximize water absorption and the adoption in partial root zone drying technology, can sustain irrigated agriculture [Yimam, et al. [63]]. The amount of soil present /accumulated in the soil could be decrease by proper utilization of plant types, and sufficient proper irrigation. Additionally, adapted and using deep rooted plant specious, which growing throughout the seasons is more advantageous than annual crop types. By doing so, the relationship between rainfall and water use may be restored, remove/reduce salt from soil's surface and plant root zone [Wei, et al. [64]]. Agriculture methods can be modified to include perennials in mixed plantings (alley farming, intercropping), with annual crops (phase farming), or in plantings that are tailored to a given site (precision farming) [Tesfa, et al. [65]]. The application of sustainable management techniques may be to mitigate decline of yield in saline soil, but their adoption is frequently constrained by their expense and the scarcity of resources or high-quality water [Mengistu, et al. [66]]. Developing effective, affordable, and easily adjustable techniques to reduce salinity stress is a significant challenge [Hailu, et al. [67]]. Globally, a great deal of research is being done to create methods of dealing with abiotic pressures, such as creating cultivars that are resistant to salt and drought, changing the dates of crops, and improving resource management techniques, among other things [Worku, et al. [68]].

Select/Use of Salt Tolerant Crops

One of the most crucial methods for addressing the issue of soil salinity is the selection and use of salt-tolerant crops, which vary in terms of their capacity to thrive and yield when planted in saline soils [Deinlein, et al. [69]]. Crops that are tolerant to salt will also be able to withstand salinity stress and use poorly quality irrigation water more efficiently [Shrivastava, et al. [25]]. Planning cropping patterns and

salinity levels for the best crop output is correlated with crops' potential relative tolerance to salinity in the soil [Sobhanian, et al. [70]]. Improved irrigation and crop management techniques can help recover the low- to moderately salinity zones. Among the commercially significant crops with varied genetic variety for improved adaptation under saline soil conditions include oilseeds (safflower and sunflower), barley sorghum, wheat, mustard, and other crops [Gebretsadik, et al. [71]]. One of the cereal crops that is commonly grown in Ethiopia's highlands is barley, which is soon to spread to areas with a moderate elevation as well. Despite being one of the cereal crops that is often grown and having a well-documented capacity to withstand stress caused by salt, barley is not widely introduced or used in marginal environments in the nation [Worku, et al. [72]].

Both qualitative and quantitative changes in protein synthesis as well as alterations in the pattern of gene expression occur in saline environments [Bekele, et al. [73]]. While it is well accepted that salt stress results in quantitative alterations in protein synthesis, there is disagreement about whether salinity triggers specific genes related to salt stress [Munns, et al. [74]]. Abiotic stress causes a plant to activate multiple genes, which raise the amounts of various metabolites and proteins. Some of these proteins may provide some resistance to the pressures, according to Alam, et al. [75]. For many years, the main goal of plant breeding projects has been to develop salt-tolerant crops in order to sustain crop yield in saline and semiarid agricultural areas [Hailu, et al. [76]].

Amelioration of Soil Salinity by Soil Microorganisms

Many methods, such as plant genetic engineering and the more recent use of plant growth-promoting bacteria (PGPB) to become functional, have been created to lessen the detrimental effects of high salinity on plant growth [Ruiz-Lozano, et al. [77]]. In order to enhance problematic soil and crop productivity, microorganisms are well known and established for their roles in promoting plant development, managing nutrients, and controlling diseases in agricultural land. Through a variety of direct and indirect processes, these advantageous microbes infiltrate plant rhizospheres and stimulate plant growth [Otlewska, et al. [78]]. According to earlier research, using PGPB has emerged as a viable substitute for reducing salinity-induced plant stress, and the significance of microorganisms in the control of biotic and abiotic stresses is growing [Hayat, et al. [79]]. For PGPR-induced physical and chemical alterations that lead to increased tolerance to abiotic stress, the term Induced Systemic Tolerance (IST) has been proposed [Hammer, et al. [80]]. Plant development is promoted by PGPR in one of two ways: either directly by producing phytohormones such as auxin, cytokinin, and gibberellins, or indirectly by lowering plant ethylene levels by enzymatic means and/or by producing siderophores [Haile, et al. [81]]. Arbuscular mycorrhizal fungus inoculations have been shown to enhance plant growth under salt stress and to improve the biophysical and chemical characteristics of soil [He, et al. [82]].

Conclusion

Sustainable agricultural land management strategies protect and increase the soil quality of the, prevent natural resource deterioration, and enhance agricultural land productivity. Abiotic stress, such as soil salinity is the serious problem influencing agricultural land resource and hampering the crop production. The significant losses of agricultural yields are mainly lost due to saline soils as well as inadequate of soil water. To address the issue of soil salinity, numerous adaptations, mitigation policies, and strategic strategies are needed. To combat salinity stress, appropriate irrigation techniques, leaching, the use of enhanced crop varieties tolerant to salt, and sustainable resource management techniques can all be helpful. In addition to this, it is crucial to create straightforward, affordable biological solutions for managing salinity stress that are both environmentally and economically sound. Plant growth-promoting hormones, nutrient availability, genetic diversity, and the dissociation of organic materials can all be enhanced by the use of biofertilizers and soil microorganisms. Crop productivity, environmental stability, ecosystem services, and food security are all improved by soil microorganisms [83-87].

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