Degraded Soils: Origin, Types and Management

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Contents

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Abstract The cultivated lands are continuously degrading and the extent is increasing because of different natural environmental and anthropogenic activities. Soil degradation due to salinization, erosion, water logging etc. makes environment difficult for plant growth resulting in reduced agricultural production. Soil physical, chemical and biological properties are affected due to alteration in hydraulic conductivity, bulk density, osmo-deregulation, poor aeration and specific ion toxicities. A number of management and reclamation technologies are available to counter these problem but the major concern is to optimize the most economical and eco-friendly technologies. Saline soils can be cultivated growing different halophyte plants and using modern irrigation practices. Conservation and effective and efficient use of good quality water help proper leaching of soluble salts in saline soils. Saline-sodic and sodic soils can be rehabilitated with different amendments, which can provide soluble calcium to replace exchangeable sodium adsorbed on clay surfaces. Different amendments can provide calcium directly to the soil or indirectly dissolving native calcium from calcium carbonate already resent in the soil. The eroded soils can be reclaimed by providing proper soil surface cover either in the form of mulching or vegetative cover by fodder or wild shrubs. Different studies demonstrate that under adverse conditions where chemical treatments are uneconomical tree plantations provide positive net returns to investment and significant net benefit and social outcomes from these lands. These findings suggest that there is great opportunity for capital investment in afforesting abandoned degraded soils with multipurpose approaches. This chapter covers the introduction to origin, extent and sources of degraded soils, along with their management and reclamation options.

Keywords Soil pollution • Salinity stress • Soil erosion • Agroforestry • Soil management

1 Land Degradation

1.1 Introduction

Degradation means undesirable and unwanted changes brought about by human activities along with natural phenomenon. Soil degradation is among serious prevailing issues in our modern era. It is badly affecting soil's natural fertility to enhance our economic values along with ecological issues. It is being caused due to natural and anthropogenic activities. The level of degradation depends on degree of degradative processes; duration of usage of such degraded land and its management. Land degradation causes exploitation of soil resources, reduces soil productivity and alters composition of vegetations; thus influencing billions of people around the globe directly or indirectly (Ravi and D'Odorico 2005).

Degradation of soils can considerably decrease the soil's capacity to produce food and consequently about 66 % of the total world's population is malnourished (Pimentel and Burgess 2013; World Health 2000). To feed the ever increasing population of world, food production needs to be enhanced (Haub et al. 2011) It is important to reverse the land degradation to achieve this modest goal as 99.7 % of our human diet calories are fulfilled by our land resources and only 0.3 % is being contributed by aquatic ecosystems (FAO 2004). To overcome our basic food demands it is most important to maintain productivity and quality of our land. Generally, soil formation process is 10 to 40 times slower compared to soil lost (Pimentel and Burgess 2013).

It is pertinent that we should look for alternative means of intensification specially use of sustainable land management techniques (SLM). It is said that utilization of land resources is to use the water, land, plants and animals resources to fulfill our present day human demands along with enhancing their productive potential and environmental functions (Quarrie 1992). SLM focus on four land sustaining techniques, improved irrigation management, rehabilitation of degraded soil, enhance pasture and grazing processes along with maintenance of our organic soil all these steps without further degradation of our resources come to meet our present food demands (World Bank 2006). Not only to maintain but also to enhance soil natural fertility it is important to increase its carbon sequester capacity along with ability to overcome climate change (FAO 2009; FAO 2010). By using SLM technologies we meet our human food demands without further degradation of our land and water resources (IFAD 2011; Lal 1997). It is evident that allowing land degradation is expensive because it has long term effects on society as well as on land owners (Costanza et al. 2014).

1.2 *Causes of Land Degradation*

The cause of land degradation for a particular area can be one or combined effects of many. (Geist and Lambin 2004) classified the causes into two categories

- proximate causes (biophysical)
- overlying causes (anthropogenic)

Biophysical have direct effect on all ecosystems like drought, soil salinity, soil acidity, metal contamination, related to extreme climatic conditions while on the other hand anthropogenic causes have indirect effect on ecosystem like intensive cropping, deforestation, overgrazing or poverty, urbanization and industrialization.

Among the proximate causes, agriculture is most contributing source of land degradation but its effect on land is aggravated by inter-related relations with other causes. Severe land degradation is observed in combination like the effect of extreme climatic changes is augmented along with poor man management techniques (McIntyre and Tongway 2005; Smith et al. 2007). It is widely reported that in

Australia, repeatedly focus on annual plants can lead to soil erosion, acidity, salinization in short cause land degradation (Bouwman et al. 2005; Lavelle and Spain 2001).

1.3 *Processes of Land Degradation*

Following are the some processes discussed which alone or in combination effect land quality.

1.3.1 Soil Erosion

Soil erosion is one of major factor causing land degradation. Erosion not only removes upper fertile layer but also causes soil crusting or sealing, soil compaction, poor soil structure, low organic matter, poor drainage and run-off. There are two agents of soil erosion i.e. wind and water, each loss significant amount of soil and reduces its productivity and quality (Lal 1990; Troeh et al. 2004). 12 % of total land area is affected by erosion globally (Oldeman 1998).

1.3.2 Soil Salinization

Land Degradation occurs due to high concentration of soluble salts, exchangeable sodium or both in such amount that decline the plant growth and soil productivity. According to (FAO 2000), of the world's cultivated land; 3.97×10^8 ha is affected by salinity and 4.34×10^8 ha of land is affected by sodicity, thus making 6 % of total land area.

1.3.3 Water Logging

Water-logging is the rise of ground water in root zone, thus having adverse effects on plant growth. According to GLASOD assessment, 4.6 M ha area of irrigated land of Pakistan and India is affected by water logging (Bridges et al. 2002).

1.3.4 Decline in Soil Fertility

According to FAO (1994), decline in soil fertility causes land degradation by (i) lowering soil organic matter, (ii) deteriorating soil physical properties, (iii) imbalance in soil nutrient status and (iv) accumulation of toxic metals.

It is said that these processes are caused by natural (erosion, salinity etc), institutional factors (improper land policies, inadequate planning) and socio-economic activities (improper land use, exploitation of forests, contamination of resources etc) (Ezeaku and Davidson 2008). These phenomenons's have devastating impacts on human-beings and on environment.

1.4 Types of Land Degradation

Land degradation can be divided into different categories like soil erosion, soil salinity and soil acidity.

2 Soil Salinity

2.1 Salt Affected Soils

Salt-affected soils can be divided into three different categories depending upon the nature of salts.

2.1.1 Saline Soils

Saline soil means soils with excessive soluble salts that retards seed germination and plant growth (Conway 2001; Denise 2003). These soluble salts exist in soil as cations and anions. Cations are calcium (Ca^{++}), magnesium (Mg^{++}) and sodium (Na^{+}), while anions are chloride (Cl^{-}), and sulfate ($SO4^{-2}$) ions. Mostly occurring salts in saline soils are sulfates and chlorides of calcium and magnesium. Small quantities of cations potassium (K^{+}) and (NH_4^{+}) and the anions bicarbonate (HCO_3^{-}), nitrate (NO_3^{-}) and carbonates (CO_3^{-2}) are also present (Appleton et al. 2009; Majerus 1996; Scianna 2002). In saline soils soluble salts are in excess while exchangeable sodium is present in small concentration thus having good physical properties, flocculated soil structure and high permeability like in normal soils (Appleton et al. 2009; Jim 2002; Majerus 1996; Scianna 2002). Such soils have electrical conductivity ≥ 4 dS m^{-1} soil reaction (pH_s) < 8.5, sodium adsorption ration (SAR) <13 (mmol L^{-1})$^{1/2}$ and exchangeable sodium percentage (ESP) < 15.

Patchy crop growth and tip burn or chlorosis of leaves of plants is observed due to salt injury in salt effected soil. These soils are also called white kallar as large quantities of soluble salts on soil surface forms efflorescence. These soils can be identified by "White alkali" which is the white crust of salts on the soil surface.

2.1.2 Saline-Sodic Soils

Soil containing both excessive soluble salts and high exchangeable sodium content to adversely affect plant growth; are known as saline-sodic soils (Majerus 1996). These soils have electrical conductivity ≥ 4 dS m^{-1} soil reaction (pH_s) > 8.5, sodium adsorption ration (SAR) >13 (mmol $L^{-1})^{1/2}$ and exchangeable sodium percentage (ESP) > 15.

Saline-sodic soils are converted into sodic soils when excess soluble salts are leached down and thus the properties of saline sodic soils changes into sodic soils having pH above 8.5, dispersed soil structure and less permeability of air and water (Denise 2003).

2.1.3 Sodic Soils

Soils having high exchangeable sodium concentration but low total soluble salts are called sodic soils (Jim 2002). Such soils are characterized by having electrical conductivity < 4 dS m^{-1} soil reaction (pH_s) > 8.5, sodium adsorption ration (SAR) > 13 (mmol $L^{-1})^{1/2}$ and exchangeable sodium percentage (ESP) > 15.

$CO3^{\ 2-}$ and $HCO3^{\ -2}$ are dominant anions of sodic soils (Qadir and Schubert 2002). At high pH and in the presence of carbonate ions magnesium and calcium got precipitated, thus the concentration of sodium ion increased in soil solution compared to other cations concentration (Majerus 1996; Qadir and Schubert 2002).

Such soils often occur in semiarid and arid areas, which are frequently mentioned as "slick spots." The combination of increased sodium concentration, decreased salt concentration and increase in Ph results in the dispersion of soil particles, result in destruction of soil structure (Conway 2001; Denise 2003). Sodic soils are termed as "black alkali" due to the deposition of organic matter on soil surface by evaporation, thus darkening the soil (Denise 2003).

2.2 Origin of Salt Effected Soils

There are various interconnected sources behind the origin of salt-affected soils; nevertheless weathering of minerals and rocks is the most predominant one in accumulating soluble salts in soils. Though the salts in ocean at present occur mainly due to the weathering process of earth crust, ocean now serves as important role in distribution of salts. Soil salinization originates from one or combination of following (Chhabra 1996):

2.2.1 Soil Weathering Process

Weathering of soils and minerals leads to the accumulation of soluble salts in soil. Under humid conditions, salts leached down in the soil due to heavy rainfall. Thus in humid regions the formation of salt affected soils is rare while in arid and semi-arid regions there is not sufficient water available to leach down these salts and consequently more salts accumulate in soil surface and result in soil salinity development. This process of accumulation of salts in soil by weathering is known as primary salinization.

2.2.2 Accumulation on the Surface Due to Irrigation Under Inadequate Drainage

Improper irrigation system transports the salt on the surface of soil profile and on evaporation this salt is left behind. So, the water build up more salt on surface compared to evenly distribution of salt in the soil profile. This leads to the formation of saline soil.

2.2.3 Shallow Water Table

Inadequate water management and unsuitable drainage system are the reason behind the rise in water table of command area. In some lands it is reported that water table rises at rate of 1–2 m per year. To some extent this water is mineralized and due to increase in water table, water continues to rise upward by capillary action and on evaporation leave the salt behind. Shallow water table is the foremost reason behind developing salty soils.

2.2.4 Fossil Salts

In arid regions, salt accumulation is also derived from fossil salts, involve some entrapped solution or some former deposits in marine. Salt release is either natural or due to anthropogenic activities. Example of naturally salt release is rise in saline ground water through impermeable layer overlying saline band. Example of human induced salt release is the construction of canals or water channels in saline strata that leads to development of salinity in the area because of using this ground water for irrigation.

2.2.5 Seepage from the Upslope Containing Salts

Salinity of downslope areas is commonly observed due to water influx in the upslope areas particularly, under certain conditions when water movement in subsurface takes place through those regions which are salts rich.

2.2.6 Ocean

Soil near coastal areas usually has high salt concentration from the ocean in the course of:

- Flooding of soil surface by sea water when waves are high;
- Entrance of sea water through rivers, inlets, etc.
- Flow of groundwater
- Aerosols generated by salt-affected areas are transported many kilometers in coastal areas. It is reported that 20–100 kg/ha NaCl in land while 100–200 kg/ha NaCl in coastal areas are deposited every year. Continuous addition of this small amount of salts in soils leads to soil salinity.

2.2.7 Chemical Fertilizer and Waste Materials

Excessive use of chemical fertilizers in fields also contributes augmentation of salts in soil, yet there input in salinity development is insignificant. Nevertheless addition of some manures like sewage sludge, cow dung or slurry and industrial material like pyrites or pressmud influence the build-up of certain ions in soil that has negative effect on soil productivity (Chhabra 1996).

2.3 Causes of Salt Affected Soils

There are two main causes of sililinty

- primary salinity (Natural process)
- secondary salinity (Anthropogenically induced salinity)

Secondary salinity is primarily due to improper irrigation system and use of poor quality water.

2.3.1 Primary Salinity

Primary salinity is a naturally occurring process mostly occur in arid and semi-arid regions where rainfall is low while evapo-transpiration rate is high, thus there is not availability of sufficient water to leach salts down to avoid salinization (McDowell 2008). Due to low rainfall, high transpiration and evaporation, salinity rises as salt concentration on soil surface increases while availability of water decreases (Bridgman et al. 2008). It is estimated that 1000 million hactares of world’s total land which is equal to 7 % of world’s area is salt affected (Rose 2004). The major contribution in salinity causes is primary salinity which is consequential of natural soil development. It mostly occurs in arid tropical areas where salinity occur naturally (Huumllsebusch 2007).

Primary salinity is also caused by natural release of some soluble salts in soil by weathering of parent material during soil development process, these soluble salts are Cl^- of Na^+, Ca^{2+} and Mg^{2+} and sometimes SO_4^{2-} and CO_3^{2-}(Ashraf and Harris 2005; Thiruchelvam and Pathmarajah 2003).

Inadequate drainage is another factor causing soil salinization; it may involve the low permeability of soil or elevated ground water. This high ground-water is often due to physiographic unevenness. The water moves from higher lands over the sloping surface towards the lower lands cause either salty lakes or temporary flooding. Under such conditions, removal of water from surface develops saline soil (Ashraf and Harris 2005). Indurate layers in soil profile and poor soil structure results in low permeability. This low permeability leads to poor drainage by restricting downward movement of water (Ashraf and Harris 2005; Thiruchelvam and Pathmarajah 2003).

2.3.2 Secondary Salinity

Secondary salinity is mainly due to disruption in hydrological cycle either through the replacement of natural vegetation with deeply rooted vegetation or through the excessive utilization or ineffective supply of water for agriculture (Beresford et al. 2004; Rose 2004). Salt affected land area is increasing day by day due to anthropogenic land-use practices (Bridgman2008). Estimated global secondary salinity rate are submitted at around 74 million hectares, with 43 million hectares irrigated land and the remaining area of non-irrigated land (Rose 2004).

Secondary salinity due to anthropogenic practices that alter the hydrologic cycle and disrupt the water balance of the soil between water irrigated and water used by crops (transpiration) (Manchanda and Garg 2008; Munns 2005). In many irrigated areas, the water table has raised due to unjustified amounts of applied water together with poor drainage. Most of the irrigation systems of the world have caused secondary salinity, sodicity or waterlogging (Manchanda and Garg 2008).

Natural salinity has been intensified from plant using more water to plant use less water cause rise in water table, when irrigation water quality is fringe or poorer (Thiruchelvam and Pathmarajah 2003). In addition, when the soil drainage may not be suitable for irrigation, the considerable rise in water table from depth of few inches to a few feet of the soil surface is occurred mainly due to irrigation. When the water table rises to 5 or 6 ft of the soil surface, ground water moves upward into the rooted area and to the soil surface. Under such circumstances, both ground water and irrigation water, contributes to the salinity. Another causes of secondary salinity are deforestation, intensive cropping, overgrazing of cattle, use of fertilizer and other amendments (Ashraf and Harris 2005; Thiruchelvam and Pathmarajah 2003).

2.3.2.1 Deforestation

Deforestation is recognized as a major cause of salinity and alkalinity of soils. Salinity is results due to migration of salts in both the upper and lower layers. That indirectly leads to the increase in temperature of surface water and reduction in average rainfall per year (Hastenrath 1991; Shukla et al. 1990). Tree covers and green vegetation's act as buffer between soil and rain. In absence of green vegetation cover top thin soil rapidly gets eroded. Rate of water run-off and sedimentation in the rivers and streams is increased due to soil erosion. That leads to flooding and soil salinization (Domroes 1991; Shukla et al. 1990).

2.3.2.2 Accumulation of Air-Borne or Water-Borne Salts in Soils

Different salts and chemicals that release from the industry and factories can enter into the soil and water and thus problem of salinity rises in the soil (Pessarakli 2010). Similarly extra water that came out from municipalities and slush are responsible for the contamination of the soil which then become the part of salinity and or alkalinity causing factors (Bond 1998).

2.3.2.3 Contamination with Chemicals

In present era use of chemicals and intense agricultural activities especially in green houses and intensive farming system playing important role in the contamination of the soil that leads to the generation of salt affected soils.

2.3.2.4 Overgrazing

Overgrazing is common where the natural soil cover is poor and hardly satisfies the fodder contents of animal husbandry mainly occur in arid and semiarid regions (Pessarakli 2010). The natural vegetation becomes scanty and salinization develops, and this process ends up in desertification due to overgrazing.

2.3.2.5 Fallowing

Soil which is uncultivated for longer period of time invites salinity because it alters the net water movement in upwards direction which results in accumulation of salts. On the other hand a soil with green top cover is useful in diverting the hydrological cycle and movements of salts downwards (Hassan et al. 2011).

Salts in the soil are electrically charged occur as ions. The main releasing sources of the ions are primary or natural sources and secondary or salinity caused by human influences (Pace and Johnson 2002).

2.4 Impact of Salt Affected Soil on Plant

Severe salt affected soils have influential role on plant growth both chemically like nutritional effect or toxicity and physically like osmotic effect. Thus due to these affects plant growth is delayed and quality of agricultural production is reduced (Denise 2003; Hakeem et al. 2013; Gonzalez et al. 2004).

There are three main reasons of soil salinization which can effect plant growth adversely (Conway 2001; Jim 2002).

- Osmotic effect hinders water uptake into the plants
- Specific ion effect causes nutritional imbalance in the plants
- Destruction of soil structure and reduction in permeability

2.4.1 Osmotic Deregulation

Water uptake by the plant from the root hairs is due to concentration gradient that exists among cell sap of root cells and soil solution. High salt concentration in the soil reduces water potential difference between plant cell and soil solution (BPMC 1996). High salt content in soil solution makes soil water potential more negative, this means that water is held more strongly in soils and reduces the movement of water into the cell. If salt concentration continues to increase making water potential more negative a level come when water may move out of cell to soil solution (Silvertooth and Norton 2000).

Due to this high negative potential, plants are unable to use soil water in spite of sufficient water availability in soil. Thus in this condition plant requires more energy to take water and it effects plant proper growth and development. Under drought condition especially in clayey soil, osmotic deregulation is more prominent as plant require more energy to take the water from the soil at given moisture level (Conway 2001; Gonzalez et al. 2004).

Reduction in plant growth, cell dehydration and possibly plant death are the consequences of high salinization in normal plant (less tolerant plants) but halophytes (salt tolerant plants) adopt certain physiological changes to survive under stress conditions (Scianna 2002). Salt stress symptoms appear in plants are similar to drought stress symptoms like stunted plant growth, change in color of leaves, curling of leaves and overall plant growth is suffered (Denise 2003). These indications may occur within a few days of plantation or after numerous weeks in young seedlings while in older or mature plants salt stress causes browning of leaves from tips and overall wilting of plants (BGS 2001).

Salt stress increases the production of reactive oxygen species (ROS) such as such as superoxide ($O_2^{\bullet-}$), hydrogen peroxide ($H_2O\ _2$), hydroxyl radical (OH•) and singlet oxygen ($1O\ ^2$) because in salt stress carbon fixation is limited in plants due to little carbon dioxide availability (Ahmad and Sharma 2008; Ahmad et al. 2011;

Ahmad et al. 2010; Parida and Das 2005; Hakeem et al. 2013). Oxidation of proteins, nucleic acid and lipids is done by these highly reactive species (ROS) and thus damages plants cells (Ahmad et al. 2010; Apel and Hirt 2004; Pastori and Foyer 2002).

Under saline conditions, production of ROS species in many plants is augmented (Hasegawa et al. 2000). Due to these ROS species, membrane damage was observed which leads to cellular injury and toxicity cause by salinization in various crop plants for example pea tomato, mustard, soybean and rice (Ahmad et al. 2009; Dionisio-Sese and Tobita 1998; Gueta-Dahan et al. 1997; Mittova et al. 2004; Hakeem et al. 2012).

2.4.2 Nutrition Imbalance

There are specific ions which have direct toxic effect on plants (Scianna 2002). Among these ions are boron, sodium and chloride which have negative effect on crop emergence, plant growth and crop development. Even the small quantities of these ions retard the plant growth (Gonzalez et al. 2004).

Furthermore, if sodium ions are present in high concentration it hinders the uptake of other nutrient ions which are required by the plants for proper growth by altering soil physical and chemical properties (Scianna 2002). This can cause disturbance in nutrient balance in the plants and upset plant mineral nutrition by impeding nutrient uptake (Conway 2001).

For instance calcium and potassium deficiency is because of high sodium concentration and nitrate deficiency usually occurs when sulfate and chlorides are in high concentration (BPMC 1996). At higher pH i.e. above seven, nutrient availability is less. Sodic soils having high pH are usually deficit in nutrient concentration (Denise 2003). The symptoms associated with nutrient deficiencies and toxicities of plants can be described by tip burning, necrosis, chlorosis, dieback and abscission (BPMC 1996).

Nutrient imbalances decrease the transport and availability of nutrients and effects plant growth. Nutrient deficiencies are usually due to the competitive effect among different ions like potassium, calcium and nitrate with sodium and chloride. Reduction in plant development and growth under saline conditions is due to ionic imbalance and specific ion toxicity i.e. Na^+ and Cl^-(Grattan and Grieve 1998).

It is reported that induction of Na and Cl concentrations while decrease in the concentration of other ions Ca, P, N, K and Mg due to rise in NaCl concentration (El-Wahab 2006).

As salinity directly affects the nutrient availability, uptake and its distribution or transport in plant, consequently nutrition imbalance arises. It is repeatedly reported the effect of salinity in lowering nutrient accumulation and uptake in plants (Hu and Schmidhalter 2005; Rogers et al. 2003).

2.4.3 Structure and Permeability Problem of Salts in the Soil

Soil salinity sometimes have negative effect on soil physical properties like soil structure and soil permeability and thus reducing plant growth (Scianna 2002).

Due to certain physical methods like clay swelling or dispersion, slaking and some specific conditions like hard setting and surface crusting, soil structure is disturbed in saline-sodic and sodic soils. These disturbances in soil may limits water and air movement, restricts root penetration, lowers the water holding capacity of plants, delays seed emergence and enhances the problem of erosion and run-off (Qadir et al. 2003). Sodic layer restricts roots emergence if it occurs near sodic soil surface. That's why if sodic clay layer develops on topsoil, most of roots movements are limited along with controlled movement of air and water (Fitzpatrick et al. 2003).

Seed germination is also affected by salinity problem along with but it is reported that salinity problem does not influence seed viability (Conway 2001).

2.5 Reclamation of Salt-Affected Soils

The most important category of degraded soils is salt-affected soils which had severe effects of salinity and/ or sodicity on agriculture production and increasing on a global scale with every day. Approximately, one billion hectares of land is affected with various concentration and nature of salts worldwide (Wicke et al. 2011). The contribution of anthropogenic salinization and sodication is approximately 76 million hectares (Oldeman et al. 1991). These activities are degrading the lands continuously on an estimated rate of between 0.25 and 0.5 Mha annually (FAO 2000). The continuous expansion of salt-affected area is particularly important in South Asia where there is fresh water scarcity at one hand and on the other hand arid to semi-arid climate coupled with low rainfall. The large extent of degraded soils is responsible for the low production of agriculture crops both quantitatively as well as qualitatively. This agriculture product is insufficient to feed the massively increasing population of the world. The core reason of low productivity form these soils is hampering water absorption by plant roots (osmotic deregulation), cell injury (the specific ion toxicity) along with deterioration in the physical properties of these soil (Abrol et al. 1988; Ghassemi et al. 1995; Lamond and Whitney 1992).

Saline soils are important land resources in world agriculture because salt-affected soils are usually abundant in natural resources like light and heat posing great potential to develop agriculture. Reclamation of salt-affected soils is of key importance to mitigate the pressure on every day squeezing agricultural soils. It will help in increasing the cultivated area and reducing the threats to our food security. Several methods have been experimented for the reclamation of salt-affected soils and the suitability of method depends upon physical, chemical and mineralogical characteristics of the soil including internal soil drainage, presence of hardpans in the subsoil, climatic conditions and types of salts, quality and quantity of available water, depth of ground water, replacement of excessive exchangeable Na+, lime or gypsum, cost of the amendments, topographic features of the land, and the time available for reclamation (Mashali 1991). The appropriate management of the constrained soil resources for the economic agricultural production is the main emphasis in agriculture. The prominent techniques include chemical, biological and agronomic or combination of these approaches to reduce the time of reclamation with in the economic bindings. The crop production and fertilizer use efficiency of these soils can be increased by an integrated approach, i.e. use of amendments preferably gypsum and organic/ inorganic manures which helps in maximizing and sustaining yields, improving soil health and input use efficiency (Swarp 2004).

Some of these possible techniques have been discussed in this section.

2.5.1 Physical Methods

Physical methods are those approaches which involve physical treatment of the soil without the application of any organic or inorganic chemicals. The physical methods include sub-soiling, deep ploughing, sanding, horizon mixing, profile-inversion and channeling irrigation practices like drip irrigation etc. These treatments increase the permeability of the soil, which is generally a limiting factor during the reclamation of sodic and saline-sodic soils. Deep ploughing is very useful where the subsoil has gypsum or lime (Ahmed and Qamar 2004). Salt-affected soils can be reclaimed by altering the methods of irrigation water applications for crop production may be providing adequate irrigation water or rainfall to leach down excessive salts from the root zone soil, and improving good internal soil drainage (Qadir and Schubert 2002; Zhang et al. 2008). In this regard, drip irrigation thought to be an effective approach to reclaim salt degraded soils. Research results proved that the leaching efficiency with drip irrigation remained higher compared to that with other irrigation methods (Bresler et al. 1982). It was observed that red effect drip irrigation on different soil properties on an unreclaimed salt-affected land (Tan and Kang 2009). Application of drip irrigation along with cropping significantly decreased salt concentration especially in upper 0–5 cm soil layer reducing salt concentration from 10.45 dS m^{-1} to 1.65, 3.49, and 0.94 dS m^{-1} on the 1st, 2nd, and 3rd cropping years respectively under field conditions. However, the big hindrance in this physical amelioration is availability of sufficient amount of good quality irrigation water and if available, have a high-cost in rural regions (Qadir and Schubert 2002; Zhang et al. 2006). For inland regions, ameliorating soil salinity can be achieved effectively by a plant-assisted approach than the physical approach (Li et al. 2008; Qadir and Schubert 2002; Zhang et al. 2006).

2.5.2 Chemical Process

The chemical methods include application of chemicals, such as gypsum, sulphur, sulphuric acid and hydrochloric acid. Gypsum is effective on both sodic and saline-sodic soils, while sulphur, sulphuric acid and hydrochloric acid are only effective for calcareous saline-sodic soils. These amendments remediate the soil by lowering the soil pH and react with soluble carbonates and replace the exchangeable sodium with calcium (Ahmed and Qamar 2004).

The reclamation of sodic soils is usually the most expensive compared to saline and saline-sodic soils but can be reclaimed by addition of chemical amendments, organic matter, deep tillage (Seelig et al. 1991). Gypsum has been recommended as an economical amendment for the amelioration of sodic and saline sodic soils (Elshout and Kamphorst 1990; Qadir and Schubert 2002; Shainberg et al. 1982). Gypsum has very low relative solubility being 0.2 % (0.2 g in 100 mL water) that may cause hinder and prolong the reclamation process for sodic soil (Carter and Pearen 1989). The solubility and efficiency of gypsum can be enhanced with application of fine ground material and with application methods. Application of gypsum in standing water can improve the efficiency of gypsum than application on dry soil surface (Choudhary et al. 2008) due to rapid dissolution in case of standing water. Similarly, powdered form of gypsum is more efficient in reclaiming sodic soils (Ali et al. 1999; Choudhary et al. 2008; Ghafoor et al. 2001). Dut et al. (1971) claimed that 52 to 72 cm water is required to dissolve 16.5 to 23.9 Mg ha^{-1} gypsum applied on soil surface. The solubility of gypsum increases by 10 folds under sodic soil condition.

Moreover, mixing of gypsum and fast removal of Na from the soil solution will speed up the exchange process (Frenkel et al. 1989). However, if the soil is dense and has poor drainage, little or none of the exchange will be removed and gypsum application will largely be ineffective rather it can increase the soil salinity. (Ilyas et al. 1997) observed higher Na, Ca, Mg, and EC values with gypsum application that were mainly attributed to poor soil permeability where the replaced Na remained in the soil solution. However, alter one year the EC and Na started to decline. Under soil conditions deep ploughing will facilitate the process of reclamation to allow leaching of Na salts.

Application of gypsum improves physical as well as chemical properties of salt degraded soils (Ayers and Westcot 1985), soil porosity (Oster et al. 1996; Shainberg and Letey 1984) and soil hydraulic conductivity (Scotter 1978). A significant decrease in soil bulk density was recorded when surface soil was treated with phosphor gypsum (Southard and Buol 1988). Ghafoor et al. (1985) observed a significant increase in grain yield of wheat with gypsum application.

2.5.3 Organic Matter

Addition of organic amendments improves soil structure increasing soil permeability (Tejada et al. 2006). Different studies revealed that there is a positive correlation between organic matter and microbial activity (Schnürer and Rosswall 1985).

Microbial population improved soil physical properties which accelerate the ameliorative process of salt-affected soils. (McCormick and Wolf 1980) observed that alfalfa residues used as an organic amendment can reduce the deleterious effects of soil salinity. Biochar is widely used as an organic amendment now a days, has beneficial effect in ameliorating salt-affected soils. Biochar improves soil structure having positive on bulk density, pore-size distribution and particle size distribution (Roberts et al. 2009; Sohi et al. 2009). Biochar benefits biophysical properties of soils increasing availability of air and water in rhizoshere which in turn improves germination and plant survival (Lehmann et al. 2006; Zhang et al. 2014).

2.5.4 Biological Methods

By planting salt tolerant plants on salt degraded soils, water evaporation considerably decreased from surface soil (Li et al. 2010; Qadir and Schubert 2002). Many field experiments revealed that planting forages in salt degraded soil, physical properties were improved due to penetration and exclusion of an extensive and thick root system followed by leaching of excessive salts to deeper layers (Liang et al. 2007). In addition, the forage cover minimized water evaporation and salt accumulation in the surface layer soil (Ghaly 2002). Phytoremediation of salt-affected soils, the soil productivity was significantly increased compared to that with simple leaching with irrigation water (Zhang et al. 2005). Biosaline (agro) forestry's most vital prospect is the controlling soil salinity and sodicity along with the reclamation of the degraded land for high yield and other agricultural production. It is reported that agroforestry have the potential to control the salinity and sodicity (Barrett-Lennard 2002; Oster et al. 1996; Qadir and Schubert 2002; Singh 1993). Thus forestry and agroforestry systems on salt-affected soils which is referred as the biosaline agroforestry can act as the supportive land use against the salinity problem. The reason behind this is the tolerance of the some salts against salinity/sodicity and their plantation can help the soil in elimination of the salinity of the soil (Singh 1993; Turner and Lambert 2000).

2.5.5 Hydro-Technical Method

In this method a saline water of high electrolyte concentration (EC) is used by keeping in view the principle of valence-dilution effect to affect soil permeability and subsequently by successive dilutions. The valence dilution effect was first validated by (Eaton and Sokoloff 1935) for reclaiming sodic soils. After the establishment of equilibrium between monovalent and divalent cations in the soil solution and the ones which are found adsorbed, application of water to the system alter the equilibrium in such a way that it will be favorable for the adsorption of divalent cations such as Ca^{2+} after the adsorption of the monovalent cations such as Na^{+}. Contrary to this situation when the soil solution is concentrated due to evapotranspiration adsorption of monovalent cations such as Na^{+} occur first and then adsorption of divalent cations such as Ca^{2+}. The ratio of divalent to total cations when concentrations are stated in $mmol_c\ L^{-1}$ of water should be at least 0.3 and with the increase in this value water requirement for the reclamation decreases. A few natural water sources have this value of this ratio but mostly some additional Ca^{2+} is required that can be added by (1) soil application of gypsum followed by irrigation with high-salt water or (2) by placing gypsum stones in the water channels to add Ca^{2+} in the salty water through gypsum stone dissolution. The major problems with this method are limited facilities of collection, conveyance, and treatment of saline water.

2.5.6 Electro-Reclamation Method

Electro-reclamation refers to the amelioration of salt-affected soils through electrodialysis. Laboratory and field investigations have shown that treatment with electric current may simulate reclamation of saline-sodic/sodic soils, although it cannot replace the conventional procedures of soil reclamation. By this method different anions such as nitrate, sulfate, fluoride, and chloride can be removed from the soil by the method of electro-reclamation. During electro kinetic reclamation, the pH increases adjacent to the anode and decreases around the cathode. The removed cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+ were 19.5 %, 34.4 %, 58.9 %, and 89.6 % respectively) and anions (Cl^-, NO_3^- and SO_4^{2-} were 47.9 %, 91.5 %, and 67.6 %) from saline soils having EC = 13.7 dS m^{-1} (Kim et al. 2013). Kim et al. (2011) found a significant decrease in EC of a saline soil (EC = 7.1 dS m^{-1}) using a hexagonal two-dimensional electrode. Generally, the removed nitrate was relatively higher than either chloride or sulfate. Sulfate tends to form insoluble CaSO4, which may decrease its respond to electro reclamation. Another study showed that chloride was concentrated on the saline soil surface (EC = 7.8 dS m^{-1}). Magnesium was not removed but potassium was removed, and sulfate showed a uniform distribution (Kim et al. 2011). The removal of Ca^{2+} was increased during pulse electro remediation of saline soils with EC ranging from 6 to 21 dS m^{-1}, as the process enhances the interactions of soil water solutions (Le et al. 2003).

2.5.7 Combination of Organic and Chemical Amendments

Use of organic amendments manifolds the process of improvement of soil properties both physical and chemical as compared to the use of chemical amendments alone. Harms of salt affected soils can be lower down by the use of organic matter (organic amendment) along with gypsum (inorganic amendment). Wong et al. (2009) reported that use of organic matter improves the physico-chemical properties of soil of the salt affected areas. Addition of farm yard manure along with gypsum reduces the EC and ESP up to the great extends (Abou El-Defan et al. 2005). Solubility of the gypsum will become two times rapid with the addition of the citrate (Jones and Kochian 1996). Citrate enhances the reclamation process by causing the complexation of the Al from solution as well as from the minerals. More decrease in dispersion and EC was observed with the combined application of organic matter and gypsum (Vance et al 1998).

2.6 Management of Salt Effected Soils

2.6.1 Management of Saline Soils

2.6.1.1 Leaching

Salt affected soils can be reclaimed by removing the salts from the root zone area of plants either with heavy irrigation or with the drainage (Feng et al. 2005; Qadir et al. 2001; Qureshi et al. 2008). Salt affected soils can be reclaimed as well as managed by irrigating the soil with plenty of good quality water. We can determine the reclamation rate by knowing the amount of water that reaches out of root zone after passing through soil referring as leaching fraction while leaching fraction is directly related to the drainage capacity of soil. Reclamation process initiates by drainage of salts and reducing the water table. There are some cases when reducing water table will no longer be beneficial but this problem can be solved by the utilization of land for crop cultivation. Brackish water used for irrigation purposes due to shortage of good quality water is the major cause of salinity problem. Salt affected soils can be reclaimed by leaching down the salts along with irrigation sources of good quality water rather using the poor quality water. 1.5 times of the EC of the irrigation water salts can be removed from the soil while adopting the good management activities. Thus if EC of the leaching water is high we need huge quantity of water to eliminate the salts from the salt affected soils. It is general recommendation that EC can be reduced up to half with every 6 in. good quality water that can pass through the soil along with salts. That's why if we have to remove the salts 30 in. downward having EC 1.5 dS/m we need 6 in. water that will move up to the 30 in. within the soil that will EC lower the EC to 0.75 dS/m. It is proved that organic matter improves the soil properties thus with the application of the organic matter drainage capacity of the soil will be enhanced that will reduce the problem of salinity. To enhance the organic matter into the soil vegetation is very important. Growing of maximum trees can act as the buffer of the soil against the generation of the salt affected soil. Addition of salts will lower down the free energy of the water by rising the osmotic potential or solute potential. Resultantly plants feel difficulty in the uptake of the water and growth and development of the plants become less. Now it is the need of the hour to reclaim the salt affected soil to get the maximum yield as food security and sustainability are becoming major problem of the world.

2.6.1.2 Irrigation Method

It is very important that how are we irrigating the soil to check down the high concentration of the salt in the root zone. It is reported that application of the large amount of water for the irrigation purposes plays supportive role for the adequate uptake of water by plants. Sprinkler irrigation is one of the best methods for irrigation especially when water shortage and salinity are the major problem. Soluble salts leach down from the root zone when irrigation is applied to the soil for the maximum time and quantity. Thus sprinkler irrigation ranks high in efficiency as compared to the flooding. It is reported by Nielsen et al. (1966) that requirement of water becomes 3 times more in flood irrigation when compared with the sprinkler irrigation for lowering the same amount of the salts. It is also beneficial that land leveling is not required for the uniform application of the water which is the basic necessity in the flooding irrigation. Similarly drip irrigation which is sometimes also called trickle irrigation is the best method of irrigation for the perennial crops and seasonal row crops. As it supply the water the water at one point only problem of salinity become minimized. Salt concentration will become less by this method by keeping the water table low. When water table will be low risk of salinity development reduces up to great extent.

2.6.1.3 Mulching

Salts come at the surface of the soil when process of the evaporation becomes faster that application of water. Even the leached down salts can come at the surface along with water with capillary rise process when irrigation will not be applied for long time especially during the fallowing of the land. Soil salinity is the major problem when water table is shallow along with the high EC of the irrigation water. But the problem salinity can be reduced by lowering the evaporation process. Evaporation become limited when soil remain covered with vegetation. It is recommended that the salinity problem become less when process of evaporation will be lowered by mulching or covering the soil (Sandoval and Benz 1966). Thus after the fallowing of land mulching will be helpful in controlling the salinity problem.

2.6.2 Management of Sodic Soils

Excess Na^+ on the cation exchange sites causes clay particles to disperse or swell, and as a consequence these soils have poor structure, low aggregate stability, and reduced water infiltration (Rengasamy and Olsson 1991). Overall, sodic soils are a poor rooting medium for plant growth and provide lowered or insufficient nutrients. Sodic soils also have reduced biological activity and function due to the limited availability of C substrates that are likely the result of lowered net primary productivity in these soils (Rao and Pathak 1996). Remediating the effects of excess Na^+ in sodic soils can be accomplished with soil amendments and land management. Calcium amendments have been shown to reduce the effects of sodicity. Calcium flocculates clay particles leading to improvements in soil structure (Frenkel et al. 1989). Calcium also replaces Na^+ on soil exchange sites and is frequently correlated with increases in soluble Na^+ (Ilyas et al. 1997). Rates of gypsum application can be calculated by taking into account soil cation exchange capacity, target SAR, and current SAR values (Ashworth et al. 1999). After chemical treatment subsurface tile drainage may be used to remove excess sodium from the rooting zone (Pessarakli and Szabolcs 1999). Subsurface drainage can also prevent salt accumulation due to fluctuations in water table depth, capillary rise, and evaporation (Abrol et al. 1988). In order to provide advice to growers with respect to whether their management strategies have begun to bring about the changes they anticipated, a tool capable of detecting short term improvements is needed. Successful remediation of sodicity may take years and can be costly (Qadir and Oster 2002). Soil health is referred as ability of soil to perform within ecosystems and use of land to sustain high yield, good environmental quality and improve plant, animal, and human health (Doran and Parkin 1994). Soil health can be determined by the use of different indicators such as a proxy for shifts in nutrient cycling resulting from land use change, amendment application and tile drainage installation will aid in the early detection of effective remediation strategies, potentially reducing the cost and environmental impact of remediation (Ella et al. 2011; Fortuna et al. 2012). Additionally identifying soil health indicators and monitoring changes in these soil properties will aid landowners in ensuring the long–term productivity of the land. Currently, biological soil health indicators are not widely used to assess remediation progress. Reclamation of the sodic soil is very difficult and mostly expenses become high than income. By following the above procedures reclamation of the sodic soil is possible but it took many years to completely reclaim this problem while following the good crop management practices.

2.6.2.1 Drainage

Soil sodicity problem can be controlled by removing the high concentration of sodium from the root zone by good drainage practice. Low water table is helpful in reducing this problem. By the development of the tile drains and by changing the topography sodic soils can be reclaimed up to the great extent. Plantation of trees especially deep rooted is also beneficial when we want to low down the problem of sodicity. Sealing of canals or lining of canals become supportive for controlling the seepage which resultantly control the problem of the sodicity. Thus good drainage property of the soil is very important in controlling the problem of the sodicity.

2.6.2.2 Tillage and Amendments

Tillage practice is considered as the physical practice in reclaiming the problem of sodicity. Tillage cause the fragmentation of the big soil colloids having the high concentration of the sodium and amendments will become the part of the soil and reclaiming process become faster. Large organic matter which has the property of slow decomposition like straw, cornstalks, sawdust, or wood shavings used for animal bedding is reported beneficial for improving soil structure and infiltration properties of soil along with the other reclamation activities.

2.6.2.3 Supplying Calcium to Improve Water Infiltration

Refining water infiltration property of soil requires lowering of the exchangeable sodium percentage (ESP) along with raising the electrical conductivity (EC) up to more than 4 dS/m (4 mmhos/cm). It can be determined by the soil texture and irrigation method that how much exchangeable sodium percentage (ESP) is required to make the better infiltration. Sandy textured soils have the capacity to bear the exchangeable sodium percentage (ESP) upto the 12 while still having good infiltration and percolation. Surface irrigation similarly can retain good infiltration and percolation with high exchangeable sodium percentage (ESP) as compared to the sprinkler irrigation. Calcium is basic need in the reclamation process of the sodic soils as it can replace the sodium and that lowering the ESP as well as SAR.

2.6.2.4 Irrigation Water Management

Irrigation water that comes from the deep wells has great concentration of bicarbonate and thus high sodium concentration as compared to the calcium and magnesium. Irrigation with such type of water for long time creates the problem of sodicity. EC and SAR are used to evaluate the infiltration problems by the application of the irrigation water.

2.6.3 Management of Saline-Sodic Soils

To reclaim the saline-sodic soils it is the important to first reclaim the sodic soil with the use of calcium to resolve the problem of high concentration of the sodium. After reclaiming the problem of the high concentration of sodium (sodicity) problem of the high concentration of salts (salinity) can be resolved simply by the application of the high amount of irrigation water. It is the basic requirement of saline-sodic soil reclamation that to solubilize the sodium first before the leaching of all other salts. The reason behind it is that if we'll not make the sodium soluble before removing all salts from root zone problem of sodicity will left over after treating the soil for salinity problem. Thus soil structure will be deteriorated that will make infiltration process either completely stop or lower down. After this destruction remediation becomes very difficult. Therefore it is necessary to determine that how much sodium problem still remaining before applying good quality irrigation water to leach salts. High EC of irrigation water and soil supports for improving soil structure, increasing water infiltration, and resist sodium from accumulation into the soil. Except this positive effect of high EC (salt) irrigation water about soil structure it is not good for crop production.

2.6.4 Adaptations of Salt Tolerant Plants

To choose the plants that have the tolerance against the salinity is the major step in reclamation of the salt affected soils. It is because different plants have different potential to uptake and accumulation of the salts to minimize the salinity problem (Conway 2001). Different species of plants show salt tolerance against salinity by developing the mechanisms like salt exclusion, uptake and compartmentalization of salts and extrusion of salts (Holly 2004). These salt tolerance plants are also referred as the halophytes. Physiological property of halophytes is usually expressed as morphological features like salt glands, salt hairs, and succulence. Plants depend on more than one tolerance mechanism for salt tolerance (Holly 2004; Naidoo and Naidoo 1999). Halophytes can adjust osmotic effects internally by accumulating high salt concentrations or they may become able to absorb more water from saline soils (AzevedoNeto et al. 2004). Salt exclusion permits plants to maintain and reduces the quantity of salts that go to growing leaves and young fruits. A few species have adopted excluder mechanisms to tolerate the salinity stress. Through this mechanism plants filter the salts in their roots and resist against the salt uptake towards the upper parts. Salt stress is tolerated by the plants by reducing germination, growth, and reproduction to specific seasons during the year and by growing roots into non-saline soil layers, or by less uptakes of the salts from the soil (BPMC 1996). Halophytes take salts from the soil and accumulate them in to their different cells and thus maintain their water potential (Andre et al. 2004). Salt tolerant plants accumulate ions in the vacuole and produce organic solutes into their cytoplasm (Marcum 2001; Taizand Eduardo 1998). This practice of accumulation of ions in the vacuole and production of the organic solutes helps the plant to take more water with an osmotic gradient without causing harm to the salt sensitive enzymes. Plants also accumulate the salts into their vascular tissues and try to avoid the exposure of chloroplast to the salts (Misra et al. 2001). Production of organic solutes also helps the plants to retain water balance between the cytoplasm and vacuoles (Holly 2004; Marcum 2001). Plants can uptake more water from the soil when water potential of the soil will be higher than the water potential of the cells of plant (Holly 2004; Taiz and Eduardo 1998).

3 Soil Erosion

Soil erosion is the detachment of soil particles by the action of wind or water. Though soil erosion is a natural process but is accelerated by anthropogenic activities like deforestation, overgrazing, improper agricultural practices and cultivation techniques. This is a widespread problem due to which our fertile ecosystems are losing their fertility and result in degradation of all ecosystems (Lal and Stewart 1990; Troeh et al. 2004).

Loss of agricultural land is observed due to human induced erosion and other related damages. This leads to desertion and lowered productivity of agricultural lands which are also somewhat made up by addition of fertilizers over many years (Pimentel et al. 1995; Young 1998). Every year almost 10 million hectares of crop-land are deserted worldwide due to soil erosion (Pimentel 2006).

3.1 Types of Soil Erosion

Erosion is mainly caused by two agents, water and wind and thus soils erosion is divided into main categories *viz.* water erosion and wind erosion.

3.1.1 Water Erosion

Water erosion is the detachment of soil particles by the action of water. Particles are detached by raindrop impact or transported by overland water flow. Raindrop impact breaks down the aggregate of soil particles into smaller parts, these suspended particles deposited in the pores between the aggregates and clog them resulting in 'soil crust' formation. Soil crusting seals the surface by blocking the spaces between aggregates, lowering infiltration rate and drainage while increasing the run-off. Uncovered land is more susceptible to rain drop impact compared to vegetative covered land. Thus more and more water is lost due to run-off, the upper fertile layer of the soil is lost and soil becomes less productive. As soil forming process is a time-taken process, it is measured that a soil loss of 1 t/hac/year is considered irreparable within 50–100 years of time span (Van Camp and Vauterin 2005).

Raindrop impact is the first stage of water erosion; it leads to sheet erosion. Sheet erosion removes upper fertile layer of soil. Sheet erosion develops into rill erosion, forming small channels. These channels become widen and lead to gully formation (Hillel 1998).

3.1.2 Wind Erosion

Erosion caused by wind is known as wind erosion. It is the severe problem of arid and semiarid regions but also observed in humid regions. Wind erosion transports very fine particles and lowers soil fertility and thus degradation occurs. It is reported by Global Assessment of Soil degradation that 42 million hectare of European land is wind eroded (EEA 2003).

There are three modes of soil movement, depending on particle size:

- Creep (>500μmalong the surface)
- Saltation (70-500 μm)
- Suspension (short-term suspension 20–70 μm; long term suspension < 20 μm) (Shao 2000).

The extent of wind erosion is determined by soil's erodibility, climate's erosivity and also influence by various other components increasing the actual erodibility of site (Sterk and Warren 2003). Climate's erosivity depends on intensity, duration, direction and frequency of wind velocity; amount, intensity and distribution of rainfall, radiation, humidity and evaporation (Funk and Reuter 2006).

3.2 Causes of Erosion

Main cause of soil erosion when land is remaining exposed to rain or wind storms. About 60,000 kcal of raindrop energy is recorded on hitting a hectare of land in New York with 1000 mm of rainfall (Troeh 1999). This highly energized raindrop result in erosion of land even on slopes to downwards. Among all types of erosion sheet erosion is most prominent of all (Troeh 2004; Oldeman 1998). The soil erosion becomes more degradable on slopes when water flowing above them carried fertile soil particles along with it into streams and valleys. Strong wind intensifies this situation displace the upper fertile layer soil particles to different distant areas.

3.2.1 Soil Structure

Structure of the soil is an important factor in the soil erosion process. The soil with weak developed structure, medium to fine in texture and having low content of organic matter are most dominantly eroded in easy ways (Bajracharya and Lal 1992). Due to less water holding capacity and low water infiltration rates these soils are more favorable to be eroded by wind and water energy.

Texture and organic matter content of soil provides ability to the soil to resist erosive conditions. They influence the water holding capacity of soil as well as make aggregates of soil particles (Chepil 1955).

3.2.2 The Role of Vegetative Cover

Coverage of plant biomass serves as a protective blanket over the topsoil to prevent it from erosion by means of wind and water energy. Coverage of plant biomass, dead or living dissipated the rain and wind energy and as a result protects the underlying soil layer from erosion. Soil particles remains in contact and are held firmly due to upper coverage (Pimentel et al. 2005). It is reported in Utah and Montana, the rate of erosion increased 200 times as the result of ground cover decreased from 100 % to 1 % (Trimble and Mendel 1995). About 60 % of forest coverage is essential to prevent forested areas from land sliding and soil erosion. Extensive loss of forests now days for irrigation lands and pasture is followed by soil erosion (Act 2002; Singh 1993).

Degradation of topsoil is most widespread in developing countries where poor irrigation practices are being used to overcome their food demands. Crop residues are being used for heating and cooking purposes and poor agriculture practices are unable to protect land from erosion. In 1990s according to an estimate 60 % and 90 % crop residues in China and Bangladesh respectively were used for fuel purposes (Wen and Pimentel 1993). According to recent estimates still in Bangladesh 50 % of all residues from rice fields and 80 % non-rice fields are used for biomass energy (Hassan et al. 2011). In China due to availability of fossil fuels the usage of crop resides are decreased (Li et al. 2012). Even they planned to burn half of the 600 billion tons of straw residues to produce electricity annually (Lal 2007). In some areas where the fuel sources are limited the roots of shrubs and herbs are burned to use as a fuel source (Juo and Thurow 1997). All such practices exposed the land surfaces and result in degradation of land by wind and water energy and result in formation of barren lands.

3.2.3 Land Topography

The vulnerability of land to water and wind forces depends on its surface exposure as well as on its topography. It is estimated in Philippines and Jamaica where 58 % and 52 % of land respectively have slopes, face 400 times per hectare more erosion rates. Steep and marginal lands which changed from forest to crop lands are more susceptible to soil erosion (Lal and Stewart 1990). Arid lands are susceptible to soil erosion as observed in India the erosion rates are 5600 times per hectares per year (Gupta and Raina 1996). Even in developed countries like United States having massive farmlands faced 13 tons/ha/year average losses (USDA/NRCS 2007). In Europe 3 to 40 tons/ha/year loss happened after every 2 to 3 years are estimated regularly (Grimm et al. 2001; Verheijen et al. 2009).

3.2.4 Disturbances

According to estimation about three-quarters of the world's soil erosion is due to depletion of soil biomass coverage (Lal and stewart 1990). A number of factors contributing this phenomenon among which is construction sites of buildings and roads. Surface coverage of land with plant dead or living reduces level of soil erosion significantly (Pimentel 2006; Soil and Water Conservation 1993).

Along with anthropogenic activities natural processes also result in soil erosion especially along stream banks due to powerful action of flowing water. 30 % or more soil erosion is recorded on steep slopes while on flat surfaces with only 2 % of slope also faces the problem of soil erosion under powerful force of wind and water.

3.3 Assessing Soil Erosion

It is estimated that about 75 billion tons of fertile soil is lost every year throughout the world due to soil erosion process (Norman 1984; Padmanabhan and Hari 2008). Soil erosion due to water force is recorded to about 76 billion tons per year (Reich et al. 1999). In 2010, Central Soil Water conservation research and training institute in Dehradun, India estimated that the fertile land loss due to erosion is 16.4 billion tons per hectare annually with total annual loss estimated to be 5.334 billion tons (The Hindu 2010). Chinese Academy of Sciences, Chinese Academy of Engineering and Chinese Ministry of Water resources in 2009, after 3 years of study reported that China's 646 communities are facing about 3.75 million km^2 soil erosion issues (Stedman 2009). A further 2 year study revealed that if this rate of soil erosion continues with this rate the food production of China is reported to decline 40 % from current rate (Jie 2010). Both China and India which occupies about 13 % of total land area with sustained agricultural practices facing about 75 billion tons of soil erosion annually. The rate of soil erosion in United States agricultural areas is estimated to decline from year 1982 to 2007, 3.06 billion tons to 1.725 billion tons (USDA/NRCS 2010).

3.3.1 Worldwide Cropland

Currently it is estimated that 80 % of world land facing the problem of moderate to severe soil erosion problems only 10 % is facing the slight erosion issues (Lal 1994; Speth 1994). Erosion in cropland areas is about 30 t/ha/year on average that ranges from 0.5 to 400 t/ha/year (Pimentel et al. 1997). It is reported that about 30 % of worlds land became unproductive and barren due to the soil erosion rates from last 40 years. Such lands are unable to utilize for agricultural purposes anymore (Kendall and Pimentel 1994; World Resources 1994).

3.4 Effects of Soil Erosion on Terrestrial Ecosystems

Productivity of terrestrial ecosystems is significantly reduced due to soil erosion (Jones et al. 1997; Pimentel et al. 2006). Water infiltration and water holding capacity of soil decreased due to increase water runoff with erosion from soil surfaces (Torah et al. 2004). Organic matter and essential soil nutrients also degraded with erosion process along with natural biota and biodiversity also significantly affected (Torah et al. 2004; Pimentel et al. 2006). Enhanced rate of erosion where increased water runoff also results in low water holding capacity along with overall damaging effect on valuable biota and soil's biodiversity (Brevik 2009; Jones et al. 1997).

As the top soil is removed by erosion, reduction in surface soil depth is observed. Due to erosion there is not sufficient soil available to support plant and thus, crop roots are exposed and consequently more yield loss. It is reported that soil erosion can alleviate the crop yield up to 30 % (Pimentel 2006).

3.4.1 Water Availability

All sorts of vegetable and fruit production require enormous amount of water for its productivity water serves as a main limiting factor on their production (Pimentel et al. 1997). According to an estimate one hectare of corn field utilize about 7 million liters of water during its 3 months of growing season (Pimentel et al. 2004) and additional 2 million of water loss due to evaporation from soil surface as result of soil erosion due to water and strong wind forces. All of these result in less water availability for growing vegetation. Enhance water runoff significantly affect water holding capacity which result less water availability for the growing crops (Pimentel et al. 1997).

3.4.2 Nutrient Losses

Essential plant nutrients such as nitrogen, phosphorous, potassium and calcium dominantly decline due to erosion. The eroded soil has three times more nutrients as compared to remaining soil surface (Young 1989). Fertile soil estimated to have 1 to 6 kg of nitrogen contents, 1 to 3 kg of phosphorous contents and 2 to 30 kg of potassium contents whereas the left over soil having only 0.1 to 0.5 kg per ton of average nitrogen contents (Schertz et al. 1989; Langdale 1992). To overcome these problems large quantities of fertilizers are being used. The cost of loss of basic soil nutrients is estimated to be about several billion dollars each year (Torah et al. 2004). If the surface of soil is about 300 nm deep the usage of commercial fertilizers and livestock manure replace the lost of nutrients but this practice is usually expensive for poor farmers and nations. Not only expensive these synthetic fertilizers also affect the human health and also result in soil, air and water pollution (Brevik 2013; Unnevehr et al. 2003; Hakeem et al. 2011; Hakeem et al. 2014).

3.4.3 Soil Organic Matter

100 tons of organic matter per hectare is usually present in fertile soil layers (Pimentel et al. 2005; Sundquist 2010). Fertile soil's organic matter typically consist about 95 % of nitrogen and 25 % to 50 % of the phosphorous (Allison 1973). Erosion typically affects the top fertile layer of soil because most of the organic matter of dead plants and animals lies in this upper layer. Fine soil particles are mostly degraded by wind and water erosion and larger particles and stones are left behind and making it unsuitable for growing vegetation. A large number of

researches report that the eroded soil contain large amount of organic matter about 1.3 to 5 times more than left over soil (Lal 1994). The reduction of organic matter in left over soil from 0.9 % to 1.4 % results in about 50 % loss in crop production and ultimately in yield (Libert 1995; Sundquist 2010).

Depletion of the nutrients, organic matter and structure of soil results in the degradation of ecosystem and also significantly affect the crop yield. Productivity of any area is dominantly affected by the results of strong wind and water erosion. Soil erosion not only affect crop yield but also significantly affect total biomass of biota and biodiversity of any ecosystem substantially (Lazaroff 2001; Walsh and Rowe 2001).

3.4.4 Soil Depth

Suitable soil depth is required not only by plants for its roots extension but also by several soil biota‘s like earthworm (Pimentel et al. 1995; Wardle et al. 2004). Soil erosion substantially reduces the soil depth from 30 cm to less than 1 cm. The space for plant roots become declined due to which plants show stunted growth.

3.5 Conservation Technologies

Mulching, vegetation, riprap, matting, terracing, retaining walls and reforestation are common treatments to overcome soil erosion (Rivas 2006). About 30 % of the world's food production is suppressed by the agricultural land degradation for last 50 years by soil erosion (Kendall and Pimentel 1994). Biomass mulches, crop rotations, no-till, ridge-till, added grass strips, shelterbelts, contour row-crop plantation are suitable techniques for soil conservation.

All these strategies mainly focus on preventing the land from erosion by wind and water force by covering the surface layer with some sort of coverage and its residues. Not leaving the land open is the best remedy to prevent soil erosion even after harvesting the crop the coverage is provided by its remains. Thus, soil cover is the best remedy against soil erosion (Pimentel et al. 1995; Troeh et al. 2004; Pimentel 2006). The risk of wind erosion alleviates if soil cover is less than 10 %, while soil covered for more than 10 % lowers wind erosion and when soil cover is 40 % complete prevention occurs against wind erosion (Morgan and Finney 1987; Sterk 2000).

Throughout the world soil erosion is putting its disastrous effects. It is continuous, slow insidious problem. 1 mm of soil is lost every year and this is so minute amount that unnoticed by framers. About 15 t/ha of soil loss over one hectare of cropland area, rehabilitation of such soil takes about approximately 20 years even if this process continues the land is not available to support vegetation. Soil erosion severely affects if it goes unchecked and result in loss of overall biota, soil fertility, organic matter and soil water holding capacity (Pimentel and Burgess 2013).

4 Soil Acidity

Acidic soils mostly have pH values less than 7 on the pH scale (Soil Science Society 2008). Acidity of the soil mainly depends on the availability of exchangeable forms of hydrogen and aluminum ions (Brady 2001; Fageria and Baligar 2003). Higher the concentration of these exchangeable ions higher is the amount of acidity in the respective soil. Acidic soil is observed to have low fertility rates, poor in physical, biological and chemical properties. Poor management of such areas results in depressed crop yield to a significant level (He et al. 2003).

4.1 Causes of Soil Acidity

Both the natural and anthropogenic activities are responsible for soil erosion process. Natural processes happen gradually and affect the soil fertility in a gradual way but the anthropogenic effects are rapid.

4.1.1 Weathering and Leaching

The present soil is formed from the parent rocks which contain both the essential and non-essential nutrients of plants. The soil form is more acidic in nature if the parent rock and material is acidic and more alkaline in nature if the parent material is alkaline. Both the acidic and basic cations are released in soil during weathering. The influx of these nutrients is mostly overcome by leaching basic cationsthat counter act with acidic cations and the preponderance of the acidic ions enhances soil acidity. The process is more active where precipitation rate is higher than evaporation, plant's transpiration rate and high temperature boost the process of weathering and leaching (Nyarko 2012).

4.1.2 Organic Matter Decomposition

Both the plants and animals take nutrients in various forms during the course of their lives. Even after their death when the process of decomposition starts these organic matters along with many sundry chemicals are again handed over to soil. In the course of this eternal process acids are continuously formed and consumed. Usually organic matter has reactive substances like phenolics and carboxylic groups. These reactive substances on dissociation release H+ ions which result in enhanced soil acidity (Seatz and Peterson 1964). Carbonic acid also formed as reaction of CO2 which is released during process of decomposition with water. Brady (2001) reported that very little soil acidity is contributed by decaying organic matter.

4.1.3 Acid Rain

Wherever there are large cities with dense concentration of vehicles and industries, acid rain forms. Rainfall is basically acid due to deposition of oxides of sulphur and nitrogen found in atmosphere due to combustion, burning of coal/petroleum products and agricultural activities. Due to these factors pH of rainwater becomes acidic and is found between 4 and 4.5 (Brady and Weil 1984). With the excessive accumulation of these acids in the atmosphere, which if not controlled significantly affect the soil and plants growth (Brady and Weil 1984). Precipitation is also an enhancing factor in soil acidity (Donahue et al. 1983).

4.1.4 Crop Production and Removal

The main goal of any agricultural system is to produce saleable products. Soil acidification suffers as a limiting factor in this way. Respiration is necessary for both plants and microbes for their survival but it result in large amount of acid production in form of carbonic acid. Black (1968) reported that this is a very minute factor because most of carbonic acid produced during this process lost in atmosphere as CO_2 (Tang and Rengel 2003). Basic cations that are usually up-taken by plants are $Ca^{2+,}$ Mg^{2+}, K^+ and also NH^{4+}, as result more H^+ dissociation by plants for their electrical balance specially when nutrients are absorbed in form of NH^{4+}(Tisdale and Nelson 1975). More the basic cations uptake more the H^+ ions release which leads to acidity in the soil.

There are basic cations available in plant especially in leaves and stem than the grains, these basic cations neutralizes the acidic effect which is develop by different processes but when these crops are removed from field either burnt, or harvested or washed away by run-off this counter effect of basic cations is gone and ultimately soil acidity increases (Chen and Barber 1990).

Type and part of crop harvested and stage of crop at harvest basically deals with the amount of these nutrient removed. Like grain has comparatively small amount of basic cations than leaves and stem portion of the plant so forages like Hay, bermuda grass and alfalfa show more positive effects on soil acidity comparative to high-yielding grain crops.

4.1.5 Application of Acid Forming Fertilizers

The soils' inherent capacity is severely deteriorated by the result of high temperature, precipitation and incessant leaching of nutrients. This deteriorated land is unable to support any vegetative crop. Usage of agricultural land without proper management practices results in enhanced soil infertility problems. To overcome these problems most of farmers use fertilizers extensively. Mostly used chemical fertilizers are ammonium sulphate (AS), urea, muriate of potash and trisuperphosphate, etc (FAO 2004). Usage of these chemical fertilizers results in enhanced crop yield. As these fertilizers are essential for high production along with this, these chemical fertilizers significantly increase the soil acidification.

4.2 Effects of Soil Acidity on Crop Production

Soil acidity significantly affects plants yield and productivity by decaling available nutrient contents. Two major factors associated with soil infertility are presence of phytotoxic substances like Al and Mn, and P, Ca, and Mg nutrient deficiency. Mostly plants uptake the nutrient in soluble form. Soil acidification cause profusion availability of elements such as Al and Mn and result in shortage of plant's essential nutrients such as P, Ca and Mg. it is noted previously that soil acidity is associated with H^+ and $Al^{3+.}$ Surprisingly, there is no deleterious effect found on plants growth by H^+(Black 1968; Rao et al 1993). Acidic soil's most of the problems are associated with Al^{3+}. Higher Al^{3+} content in acidic soil results in reduced function and root proliferation. Roots mostly observed are stunted and club shaped. This reduces the plants availability to extract nutrients and water from soil. When aluminum is abundant it mostly fixed with phosphate in form of aluminum phosphate and making P unavailable for plant (Black 1968; Rao et al. 1993). Except molybdenum the availability of micro-nutrient boosts the soil acidity.

4.3 Management of Soil Acidity

Soil acidification is a natural ongoing phenomenon which is aggravated by human activities. With the usage of proper irrigation techniques and practices soil acidification and its harmful effects should be controlled. (Obiri-Nyarko 2012) reported techniques that how such soil acidified land should be used for sustained agricultural purposes. To overcome soil acidity issues use of organic material and lime, acid tolerant crop varieties are used. Among which use of lime and organic material combination is best in combating soil acidification problems and making soil vulnerable for irrigation practices. There is also an immense need to limit the extensive use of chemical fertilizers for combating soil acidification problems because such practices extensively enhanced soil acidity. In such areas where extensive use of lime along with organic material is a problem best remedy there is to use acid resistant crop verities.

4.3.1 Liming

Different liming materials such as dolomite lime ($CaMgCO_3$), limestone ($CaCO_3$), quick lime (CaO), slaked lime ($Ca(OH)_2$) usage are best remedies for overcoming soil acidity problems. They are used both separately and in combined forms. These liming materials along with lowering soil acidity also counteract the effect of H^+ and Al^{3+} ions (Fageria and Baligar 2005). Several other advantages of liming materials include increasing the plants essential nutrient such as Ca, P and Mg availability and reducing the toxic effect of various micro elements (Naidu et al. 1994). Liming material addition also reduce the leaching and solubility of heavy metals (Lindsay 1979; Sauve et al. 2000). Excessive nutrient availability significantly improve crop yield to substantial amounts by addition of liming materials. Soil texture, soil fertility, crop rotation, crop species and usage of organic manure are the several factors which affect the application of liming materials (Fageria and Baligar 2008).

(Sadiq and Babagana 2012) reported that application of lime material on paddy fields significantly lowers the soil acidity. In Southeast Asia acid sulfate is mostly recommended for this purpose. Application of lime in rice fields results in high Al and Fe precipitation which is responsible for their enhanced yield. Some authors also reported that high amount of Al ions contents result due to use of lime and put deleterious effects on underlying soil.

At pH 5 aluminum ions starts precipitation from soil solution. This happened due to reaction of ground magnesium Limestone GML was combined with acid sulfate soil; both of these disintegrated immediately and start releasing hydroxyl ions. Shazana et al. (2013) reported that the actual reason behind increase in soil acidity is the release of hydroxyl ions on application of ground magnesium Limestone.

(Shazana et al. 2013) reported that ground basalt is advantageous for plants as it contain plant's essential nutrients like K and P, than ground magnesium Limestone GML. The one disadvantage of ground basalt applications is it takes time to completely dissolve in soil. It is reported that in Malaysia soil content is poor in organic matter. Application of ground basalt by acid sulphate ameliorate infertile land, is highly recommended for sustained rice yield along with different organic fertilizers few months before growing season.

4.3.2 Application of Organic Materials

The organic material usage defines simply all the forms of organic materials originated from both the plants and animals. Application of organic material where improves soil's properties and fertility along with it also reduces the effect of soil acidity and aluminum ions concentration. Plants usually contain excessive amount of cations, synthesis of organic acid anions simply used for balancing cations and anions (de Wit et al. 1963). Decarboxylation of these organic acid anions results due to microbial decomposition (Tang et al. 1999; Yan et al. 1996).

It was reported that anion organic acid decarboxylation requires proton to complete its reaction during microbial decomposition (Noble et al. 1996). By up taking such proton, hydroxyl ions concentration increases which results in increase soil alkalinity. Higher the amount of cations in soil greater is the effect found on soil acidity. Plant species of legume plants such as soybean, red clover and acacia found to have higher concentration of Ca, Mg and total cations contents than non-legume crops such as maize and sorghum, also have higher content of ash alkalinity (Bessho and Bell 1992; Pocknee and Sumner 1997; Wong et al. 2000). Wong et al. (2000) also indicated that organic material associated functional groups results in increase alkalinity of soil by consuming higher content of protons.

4.3.3 Use of Acid Tolerant Crops

Several plants grow well in acidic soil due to their variant degree of acidity tolerance. Thus, we can lower the acidification rate by using acid-tolerant crops. Acid-tolerant crops are very helpful because:

- They reduce the rate of acidification by efficiently using the nitrate and soil moisture
- Limestone if not added where and when is required, the acid-tolerant crops continues the cash flow
- In liming cycle of 10–15 years, acid-tolerant crops are trying to match up with the declined pH
- On the soils having acidic sub-surface layers, it is more suitable or economical to use acid-tolerant crops rather than liming them (Upjohn 2005).

Chillies, sweet and Irish potatoes show higher degree of acidity tolerant values. They show significant growth under pH values below 5.5. Cassava and rice are best grown crops for such acidified lands (Rao et al. 1993). It is reported that most of the lowland areas in Ghana show enhanced rice yield over 1 million hectares. This land is giving outstanding yields of rice (Wakatsuki et al. 2005).

Upon the growth of most of the crops, soil acidity and aluminum toxicity put a limiting factor over their yield. Krstic et al. (2012) studied various factors of Western Serbia region such as soil pH, exchangeable acidity and aluminum ion toxicity of soil. Aluminum puts very hazardous effects on root growth and extension, significantly effecting roots water and ions uptake capacity. Usage of genetically adapted plants for aluminum toxicity is best remedy to use on such affected land under low environment impact. Availability of Aluminum tolerant germpalsm of maize had made it a suitable crop for this practice. Crops that reflect tolerance to aluminum toxicity are the best options to be chosen as acid-tolerant crops.

No doubt, acid-tolerant crops reduce the rate of acidification but they cannot stop the process. The process continues and eventually, if not properly treated, soil will become more acidic.

4.3.4 Agroforestry

Agroforestry refers to use the land for both woody perennial plants along with agricultural crops from very simple to dense systems. It comprises of very simple to complex systems. It involves a wide range of practices such as intercropping, multiple cropping, trees plantation on contours, establishing shelter belts etc. all these practices result in enhanced land yield and production by providing suitable micro-climate, permanent cover, increased infiltration, improved soil structure, organic carbon content and promoted soil fertility (WOCAT 2011).

All such practices lowers the demand of land for mineral fertilizers (Garrity et al. 2004; Schroth and Sinclair 2003).

Agroforestry's main focus is on proper land management by conserving the soil along with enhancing soil fertility and productivity especially in tropics. It focuses on the deliberate use of land for trees and crops at the same time. A large number of effects have been reported through this interaction. Essential nutrient such as Ca, Mg, and nitrate's leaching to deeper soil zones are compensated by deep rooted species and return by litter fall. (Ridley et al. 1990) reported that significant reduction of nitrates is documented by growing crops with deep rooted species such as perennial grass, multipurpose trees or shrubs.

Agroforestry plans also results in reduced rate of erosion through rain drop and by leachability of nutrients. By using proper tree species this agroforestry system also help in reducing soil acidification. It is reported that plantation of nitrogen fixing tress such as Gliricidiasepium and Albiziazygia ameliorate the acid infertile rice field in Ghana (Baggie et al. 2000). Both of these trees Albiziazygiaand Gliricidiasepium due to their high cation content increased the soil pH from 4.4 to 5.1 and 5.3 respectively.

It was reported several strategies for understanding and management of Kenyan soil for enhanced crop yield (Kisinyo et al. 2014). They improved the soil by applying organic and inorganic materials and planating crop germplasm as Al tolerant varieties. Application of lime, Phosphorous fertilizers and OMs promote soil pH and lower the Al toxicity on Kenyan acidic soil. Application of lime, P fertilizers and OMs has resulted in increased maize production from 5–57, 18–93 and 70-100 % respectively on Kenyan soils. Development of crop cultivars for Al toxicity tolerant and low Phosphorous availability also results in significant increase in crop production on Kenyan soils.

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