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Salt Affected Soils Their Identification and Reclamation

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Abstract: Salt affected soils are found throughout the world especially in arid and semi arid regions. Soil salinization is mainly due to the use of saline water for irrigation, seepage from the canals, an arid climate, evaporation of salty soil waters from the soil surface over shallow water tables and poor drainage. Salt affected soils are grouped into saline, alkali and saline-alkali soils. Three different ways viz. scrapping, surface flushing and leaching are normally used for reclamation of these soils. Reclamation of salt affected soils by leaching is the best way of reclamation. Continuous and intermittent leaching are two techniques of water application during the leaching process. Continuous leaching is quicker but it consumes more water than intermittent leaching. Soil amendments (gypsum, sulphur or sulphuric acid) are usually needed for the reclamation of soils with high sodium content. By planting trees in soils with high water table and no drainage, soil reclamation process can be accomplished. Soil salinization can be prevented by using good quality water and by managing water table below root zone by providing surface or subsurface drainage.

Key words: Leaching, Gypsum, Alkali, Saline, Reclamation

Introduction

The problem of salt affected soils has become a global issue because of poor land and water management practices as well as insufficient reclamation operations in many parts of the world. Salt affected soils are found in arid and semi-arid climates in more than one hundred countries of the world (Szabolcs, 1991). The total area of salt affected soils in the world is about 95.5 million hectares (Kovda and Szabolcs, 1979). Salinization and sodification of soils is increasing day by day in arid and semi-arid regions, for example in Australia, India, Pakistan and the Middle East (Dahiya and Dahiya, 1977; Kovda and Szabolcs, 1979; Bressler *et al*., 1982). It is estimated that the world as a whole is losing at least 3 hectares of fertile land every minute due to salinization /sodification (Abrol *et al*., 1988). According to estimates by FAO and UNESCO nearly 50% of the irrigated land in the arid and semi-arid regions of the world have some degree of soil salinization problems. This Fig. indicates that magnitude of the problem that must be tackled in order to meet future global food requirements. Realizing the nature of problem, United Nations adopted a resolution in conference on desertification held in Nairobi in 1977 that "It is recommended that urgent measures to be taken to combat desertification in the irrigated lands by preventing and controlling water logging, salinization and sodification by modifying farming techniques to increase productivity in a regular and sustained way; by developing new irrigation and drainage schemes where appropriate always using and integrated approach; and through improvement of the social and economic conditions of the people dependent on irrigated agriculture."

The existing cultivated lands are unable to meet the increasing food and fiber requirements of the world. In the past, much of the demand for growth in food and fiber production has been met by increasing the land under irrigated agriculture. Today the availability of new land is limited, while on the other hand, due to over irrigation, high water tables and poor water management practices, fertile and productive soils are turning into non-productive saline/sodic and waterlogged soils, which result in less crop production and eventually abandonment of the land. Thus, reclamation of existing salt affected soils is of primary importance.

Salt Affected Soils and Their Identification: Soil salinization is the accumulation of the soluble salts of sodium, calcium, and magnesium in the soil root zone. These salts can affect soils to the extent that crop production is severely decreased. High levels of salt limit plant growth by increasing osmotic pressure of the soil solution, which reduces the plant's capacity to withdraw water from the soil. Depending on salt concentration (EC), Exchangeable Sodium Percentage (ESP) and pH of the soil solution salt affected soils divided into three categories, saline, alkali and saline-alkali soils.

Saline soils are those soils, for which saturated extract contains salt concentration of greater than 4 dS/m at 25 ^{0}C or 2600 ppm, ESP less than 15 and pH 8.5. Alkali soils contain EC less than 4 dS/cm, ESP greater than 15 and pH greater than 8.5. Whereas saline-alkali soils contain EC greater than 4 dS/cm, ESP greater than 15 and pH greater than 8.5.

Characteristics of Saline Soils: In saline soils, the salinity does not affect the physical properties of soil, but it is harmful because elevated soluble salts in the soil solution reduce the availability of soil water to plants.

White Surface Crust: As water evaporates from saline soils, salts which were in the water, are left behind to accumulate on the soil surface. The salts are light colored and when accumulate has continued for several weeks they form a very thin film on the soil surface.

Good Soil Tilth: Excess salts keep the clay in saline soils in flocculated state so that these soils generally have good physical properties. Structure is generally good and tillage characteristics and permeability to water are even better than those of non-saline soils.

Poor Yield: Crop production is usually less than normal from saline soils. Salts tie-up much of the water in the soil and prevent plants from absorbing it by osmotic pressure. Seedlings are the most sensitive to water stress and crop stand is reduced because of seedling death and poor yield results.

High Soil Fertility: Soil that has been saline for several years will usually be fertile, with high Nitrogen (N), phosphorous (P) and potassium (K). These nutrients build up in salty areas when there is little removal by crops and the area is fertilized each year.

Characteristics of Alkali Soils: In these soils sodium ions disperse the mineral colloids, which then form a tight soil structure. This structure slows the infiltration/percolation of water.

Poor Soil Tilth: The excess sodium in alkali soils does not allow soil particles to attach one another. As a result soil is dispersed and not friable. Instead alkali soil is greasy when wet. Fine textured clay soils are often very hard and when dry. Poor seed germination is common because good seedbed preparation is seldom accomplished.

Low Soil Permeability: Large (macropores) in the soil which provide passage for water movement become plugged due to dispersed clay and humus. As a result soil permeability becomes low. Hence the subsoil may be very dry even though water is ponded on the soil surface. Salt tolerant plants that germinate often suffer water stress and may eventually die.

Black Surface Crust: Alkali soils because of dispersion of the organic matter can be identified from the black color of the soil surface.

Causes of Salt Accumulation on the Soil Surface: In the humid regions of the world, salts near the surface of the earth are transported to lower soil layers by seepage originating from rainfall, and by surface streams to the ocean. On the other hand, in arid regions the salts on the soil surface are not transported away because of insufficient rainfall. Also salts already in the lower layers of the soil return to the soil surface by capillary action during hot seasons.

The main causes of salt accumulation in soils are: (i) use of saline water for irrigation of lands, (ii) seepage from canals, (iii) an arid climate, (iv) evaporation of salty soil waters from the soil surface over shallow and fluctuating water tables (Michael, 1978) and (v) poor drainage (Bernstein, 1962; Dahiya and Dahiya, 1977). All these factors, either singly or in association with other factors, are responsible for the development of salt affected soils in the world. The most common process of soil salinization is shown in Fig. 1

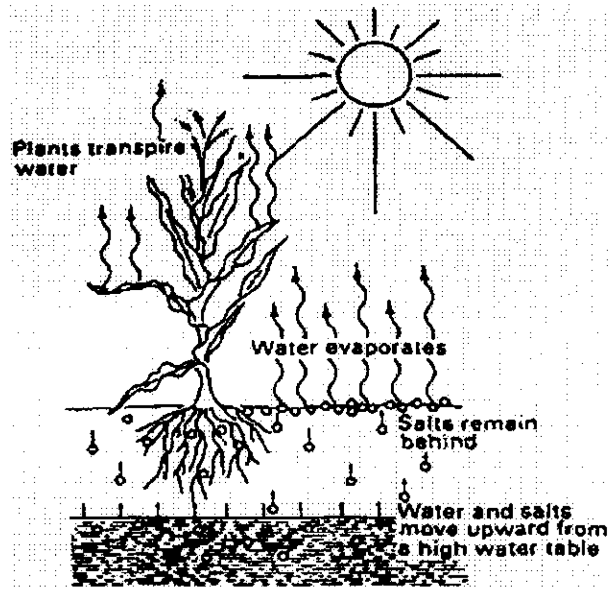

Fig. 1: Soil Salinization Due to High Evaporation from the Shallow Groundwater Table

Reclamation of Salt Affected Soils: The processes and practices involved in bringing salt affected soils into productive condition are known as reclamation measures. The term 'reclamation of salt affected soils' refers to the methods used to remove soluble salts from the root zone. To improve crop growth in such soils, excess salts must be removed from the root zone. Methods commonly adopted or proposed to accomplish this include the following:

(a)Scraping (Physical Removal): Reclamation of a soil on a temporary basis can be done by scraping off the salt crust, so that the salts that have accumulated on the soil surface are removed by mechanical means. After the topsoil layer is disposed of, the lower layers with less salt content are cultivated. This method is based on the idea that the lower layers of the soil profile have a lesser accumulation of the salts than the surface layer. This method has resulted in only a limited success. Although this method might temporarily improve crop growth, the ultimate disposal of the salts still poses a major problem. The scraping of the top layer will decrease salts in the root zone for longer periods only when scraping is followed by leaching.

(b)Flushing : Washing away the surface accumulated salts by flushing water over the surface is sometimes used to desalinize soils having surface salt crusts. Because the amount of salts that can be flushed from a soil is rather small, this method does not have much practical significance. Also a sufficient downward gradient is required to carry the water away, therefore, this method is not practical in landlocked fields.

(c)Leaching: Leaching is the only effective way to decrease excessive salts from the root zone of the salt affected soils. This is the process of dissolving and transporting soluble salts by downward movement of water through the soil by applying excessive water onto soil surface. It involves the dissolution of soluble salts in the soil and the passage of the resulting solution through the soil profile and the consequent removal of salt from the root zone by drainage. Its efficiency can be defined as the quantity of soluble salts leached per unit volume of water applied to the soil (Tanji, 1990). The efficiency of leaching depends largely on: (i) the amount of water applied, (ii) the uniformity of the water distribution in the soil and (iii) the adequacy of drainage. It is important to have a reliable estimate of the quantity of water required to accomplish salt leaching. The initial salt content of the soil, the desired level of soil salinity after leaching, the depth of the root zone to which reclamation is desired and the soil characteristics are the major factors that determine the amount of water needed for reclamation. A useful rule of thumb is that a unit depth of water will remove nearly 80% of the salts from a unit soil depth of structureless soils (Reeve *et al.*, 1955). Thus 30 cm water passing through the soil will remove approximately 80% of the salts present in the upper 30 cm of soil. Hence for leaching one hectare of the saline soil up to 1 m will require one hectare-meter of good quality water. By using various leaching techniques this wastage of irrigation water can be minimized. However, for more reliable estimates it is desirable to conduct salt leaching tests on a limited area and observe the leaching process.

Methods of Water Application During Leaching: Generally two practices of water application are traditionally used to leach the salts from soil: (i) continuous leaching, in which the water is continuously ponded on the soil surface and the leachate discharges to the deep water table or to drains; and (ii) intermittent leaching in which ponded water application is interrupted with *rest* periods allowing redistribution of the salts held in micropores.

Continuous ponding of water on the soil surface is the traditional extensively used method of salt leaching on surface irrigated lands (Tanji, 1990). During leaching with continuous ponding, the water flows mostly in the macropores with salts in the micropores having to diffuse to the mobile water. Oster *et al.* (1972) and Hoffman (1980) reported that with increasing macropore flow the effectiveness of solute removal decreases. This method takes less time than other methods of leaching but it consumes large quantities of water, which percolate downward to the shallow groundwater table carrying salts in the leachate.

Several experiments have been conducted to investigate the improvement in the efficiency of leaching and it has been observed that leaching efficiency increased under intermittent leaching (Oster *et al.*, 1972; and Dahiya *et al.*, 1981). Dahiya *et al.* (1981) observed that leaching intermittently allowed more time for the movement of water through pores and improved the leaching efficiency. Al-Sibai *et al.* (1997) worked on the movement of solute through porous media under intermittent leaching and reported that under intermittent leaching, 25% of water savings were possible under their laboratory conditions. Therefore they concluded that intermittent leaching could improve leaching efficiency.

Factors Affecting the Intermittent Leaching: When the leaching is carried out in warm climates, the salts that are leached to shallow depths may move back to the surface by capillarity during *rest* periods of intermittent leaching due to the high evaporation from the soil surface (Minhas and Khosla, 1986). Also due to the high evaporation, large quantities of water are lost and thus the quantity of water actually available for salt leaching to lower layers is decreased. Minhas and Khosla (1986) found no difference in the leaching of chloride during intermittent and continuous leaching under high evaporation rates. However, they found a significant difference in leaching during periods of low evaporation rates. Intermittent leaching is efficient in well-structured soils because there is a slower upward capillary flux in the structured soils that minimizes the water losses during *rest* periods.

The low hydraulic conductivity of the soil allows ample time for the solute to diffuse out of the soil aggregates even when leached under continuous leaching. This reduces the advantage of using intermittent leaching. Verma and Gupta (1989) found only a marginal decrease in soil salinity with intermittent application compared with continuous leaching. They attributed this to the low hydraulic conductivity of their clayey soil.

Water Losses During Leaching Due to Proximity of Soil to Drains: During leaching of salt affected soils it is observed that salts from the area near drains leach very quickly compared to that away from the drain. As the distance from the drain increases, streamlines become longer. Short streamlines mean rapid leaching and long streamlines mean slow leaching. After some time the soil close to the drain is completely leached while that further away is only partially leached. This leads to inefficiency in water use.

Youngs and Leeds-Harrison (2000) carried out a study on the wastage of irrigation water during reclamation of the coarse textured soil with sub-surface drains. They estimated numerically that for a land with 2 m deep and 40 m drain spacing, the percolation of water from the area within 5 m distance from the drain is 77.5%, while only 4% of water is lost from the area which is between 15 to 20 m away from drain. Therefore they proposed progressive leaching of the soil to decrease the wastage of water from the soil near the drain. With progressive leaching the area between drains is divided into small areas by constructing bunds. The area A is ponded first and leached, then areas B, C and D are ponded and leached progressively as shown in Fig. 2. They calculated that water savings of up to 84% and time saving of 76% were possible by using their proposed progressive technique of leaching.

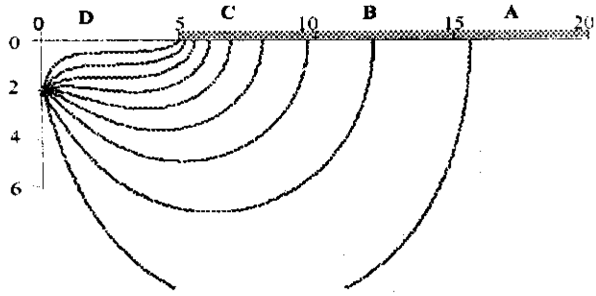

Fig. 2: Progressive Method of Leaching of Soil with 2 m Deep and 40 m Drain Spacing (Youngs and Leeds-Harrison, 2000)

Soil Amendments: Gypsum, sulphur or sulphuric acid are the most commonly used soil amendments. Whether an amendment is necessary or not for the reclamation of salt affected soils is a matter of practical importance. Saline soils are often dominated by neutral salts therefore an amendment may not be needed. In case of alkali or saline-alkali soils where high amounts of sodium salts are present an amendment should be added for loosing sodium from the soil before it can be leached. Gypsum is the most effective soil amendment for removing sodium from the soil particles. Gypsum is a slightly soluble salt of calcium and sulfate. Therefore it will react in the soil slowly, but, for a long time. The amount of gypsum required will vary widely depending upon the percentage of exchangeable sodium and the soil texture. This relationship is given in Table 1. When the required amount of gypsum exceeds five tons per acre, the rate should be spilt into two or more applications of no more than five tons at one time. The gypsum should be incorporated at a depth of about one or two inches, enough to mix it well with surface soil.

Table 1: Gypsum Requirement in Tons per Acre in Relation to Soil Texture and Sodium Percentage.

	Exchangeable Sodium Percentage				
Soil texture	15	20	30	40	50
	Tons per acre				
Coarse	2	3	5	7	9
Medium	3	5	8	11	14
Fine	4	6	10	14	18

Drainage: In order to permanently improve the salt affected soil, it is necessary to not only leach salts, but also to have adequate drainage. The drainage system must provide an outlet for the removal of the leachate as well as keep the water table deep enough to prevent salt laden groundwater from moving up to the root zone. This is particularly a problem for soils with a shallow, saline water table (Schilfgaarde, 1974). Tile drains and open ditches are effective for removing subsoil water that accumulates due to compacted clay layer or bed rock.

A Silvipastral System as an Alternative: In the absence of a safe outlet of drainage water, the conventional methods of reclamation through leaching and drainage are not possible. The alternative is known as silvipastral system. This system utilizes trees in place of traditional crops to reclaim salt affected soils. By removing water from lower layers of the soil, the trees minimise the capillary rise and therefore shift the zone of salt accumulation from the surface to lower layers. Trees, because they use large quantities of water as compared to crops, intercept the seepage from canals, which helps to control soil salinization by preventing rise in water table. When a particular area has a shallow water table, the large scale planting of trees can biodrain the excess water and lower the water table. Trees also help to lower the salt content in the soil by absorbing salts from the soil. On the other hand a good return can be earned by selling trees production in the market.

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