SALT-AFFECTED SOILS

Salt-affected soil is a general term used for those soils which have been adversely modified for the growth of most plants because of the presence of excess soluble salts, exchangeable sodium (Na) or both. Salt-affected soils are found in all the continents and under almost all types of climates. However, their distribution is wide spread and extensive in arid and semi arid regions as compared to humid. Nature and properties of these soils are diverse and require specific approaches for management and reclamation to maintain their productivity.

Importance of salt-affected soils

- Pakistan spreads over an area of 79.61 million hectares (M ha)
- The country is the ninth biggest nation of the world in terms of population.
- Population will be 201 million in the year 2010.
- Land resources of the country are degrading, causing environmental problems
- Almost 70 % of the country falls under arid and semi-arid regions.
- In irrigated belt salinity is threatening about 6.68 M ha.

EXTENT OF SOIL SALINITY/SODICITY PROBLEM IN PAKISTAN (Area in mha)

Sr. No.	Category	Punjab	Sindh	Baluchistan	NWFP	Pakistan
1	Saline sodic porous	1.1070	0.3185	0.1654	0.0316	**1.6225**
2	Saline sodic dense	0.8358	0.0395	0.0022	-	**0.9275**
3	Saline sodic gypsifrous					
i	Porous	0.0507	0.0214	0.1931	-	**0.2652**
ii	Dense	0.0570	0.0269	-	0.0075	**0.0914**
4	Saline	-	0.3351	0.6363	-	**0.9714**
5	Saline gypsiferous					
i	Porous	0.1666	1.2454	1.3167	-	**2.7287**
ii	Dense	-	0.0733	-	-	**0.0733**
	Total:-	2.2171	2.1101	2.3137	0.0391	**6.6800**

Source: Soil Survey of Pakistan (1998)

CLASSIFICATION OF SALT-AFFECTED SOILS

Generally soils are classified into these three classes keeping in view the salt type.

1. Saline soils: A soil having sufficient amount of soluble salts to adversely affect the growth of most crop pants but not containing excessive exchangeable Na^+. Most of the soluble salts in saline soils are composed of cations Na, Ca and Mg and of anions like Cl, SO_4 and HCO_3. Small quantities of cations K and NH_4^+ and anions NO_3, CO_3 and BO_4 also occur in these soils. Saline soils have:

$EC_e > 4$ dS m^{-1}

SAR ≤ 13

ESP ≤ 15

$pH_s \leq 8.5$

2. Sodic soils: A soil having sufficient amount of exchangeable Na^+ to adversely affect the growth of most crop plants but not containing excessive soluble salts. Soil properties like structure, aeration, hydraulic conductivity are deteriorated by the excessive amount of exchangeable Na^+. Sodic soils have:

$EC_e \leq 4$ dS m^{-1}

SAR > 13

ESP > 15

$pH_s > 8.5$

3. Saline-sodic soils: A soil having both soluble salts as well as exchangeable Na^+ in sufficient amounts to adversely affect the growth of most crop plants. A saline sodic soil has:

EC > 4 dSm^{-1}

SAR > 13

ESP > 15

pH_s may or may not more than 8.5

In some literature, the term “alkali” is used in place of sodic, i.e. for soils having excess exchangeable Na^+. Hence, the terms “saline-alkali” in place of saline sodic and “alkali” in place of sodic are used. However, the use of the term “alkali” is being discouraged because of its ambiguity with the term “alkaline” which refers to the soils having pH > 7.0.

Soil Type	EC_e (dS m^{-1})	ESP	SAR	pH_s
Saline	≥ 4	< 15	< 13	< 8.5
Sodic	< 4	≥ 15	≥ 13	≥ 8.5
Saline sodic	≥ 4	≥ 15	≥ 13	≥ 8.5

Genesis/Formation of Salt-Affected Soils (causes of salt-affected soils)

Soil genesis refers to the mode of origin of the soils with special reference to the processes and factors of soil formation for the development of the soil from unconsolidated parent material. Genesis includes reducing the size of parent material particles, rearranging the mineral particles, adding organic matter and other materials like salts, changing the kinds of minerals, creating horizons and producing clays. It is a continuous but slow process. The following factors mostly contribute towards the genesis of salt-affected soils in Pakistan.

1. **Salty parent material:** The original and major source of salts is the primary minerals in parent material which serve as the parent material for soil formation. In Pakistan, like most of the arid and semi arid regions of the world, precipitation is inadequate for leaching of salts out of the root zone. Consequently, soluble salts and exchangeable Na have been accumulated for thousands of years during the process of soil formation. This is the case of primary/old/ancient salt-affected soils. These soils existed before the advent of the canal irrigation system in the Indus Plains of Pakistan.
2. **Uneven distribution of rainfall:** Most of the rainfall occurs during monsoon (July-August) while during major part of the year the salts present in the soil tend to move upward with water through capillary action. At the soil surface, water evaporates and leaves behind salts on the surface.
3. **Aridity:** Most of the soils of Pakistan are located under arid and semi arid region. The rainfall that is received during a year is not sufficient to leach away the salts from the root zone, i.e. there is not upward movement of water in the soil.
4. **Physiographic unevenness:** Micro unevenness of the soil surface is generally not observable. This situation can be visualized from the different depths of standing water after rainfall. The rain water flows from the convex parts over the sloping parts and is accumulated on concave parts. In parts where there is low effective leaching, accumulation of salts takes place. Hence, patches of salts develop in an uneven soil.

Considering the entire Indus Plain of Pakistan, there is almost zero slopes due to which natural drainage is poor which promotes the salination and sodication processes.

5. **Irrigation (Genesis of Secondary or man made salt-affected):** Brackish under ground water is another and important source of causing salt-affected soils. Secondary or man made salt-affected soils have formed after the introduction of artificial canal irrigation system in Pakistan. The extent of secondary salt-affected soils is very small than primary salt-affected soils. Insufficient or unequal application of irrigation water, imperfect soil drainage, waterlogging, poor quality of ground water, lack of proper management of soil & water, seepage from canals and water courses or combination of these factors are the major causes of formation of the secondary salt-affected soils.

Reclamation of Salt-Affected Soils

Objectives of Reclamation: The main objectives of reclamation are as under:

1. To increase crop yield per unit area and thus overall production of all crops.
2. To increase water use efficiency through reclaiming patchy salt-affected soils occurring in association with good soils and thus increasing crop production per unit of irrigation water applied.
3. To improve farmers' living standard and life style through increased yield from a given
    i. Area of land
    ii. Quantity of irrigation water
    iii. Amount of fertilizers and other inputs.

Pre Requisites of Reclamation

a. Crust removal
b. Leveling of land
c. Deep ploughing
d. Strong boundaries of fields
e. Soil sampling and analysis
f. Good subsurface drainage
g. Arrangement of sufficient amount of good quality water

VARIOUS METHODS OF RECLAMATION - (Approaches of reclamation)

I. **Physical or mechanical reclamation:** Use of machinery i.e. deep ploughing, sub-soiling, profile inversion, vibro drainer, rotavation, sanding, chiseling and crust removal.

II. **Biological Reclamation**: Addition of organic material and growing of salt tolerant grasses, crops and bushes / trees.

III. **Hydrological or hydro technical reclamation**:

   a. Installation of drainage system (Tile drain and open drain).

   b. Boring of tube wells.

   c. Leaching of salts through excessive irrigations.

IV **Chemical reclamation:** Addition of chemical amendments, mixing and subsequent leaching.

V **Integrated Approach:** Combination of two or more of the above approaches.

Reclamation of Saline Soils

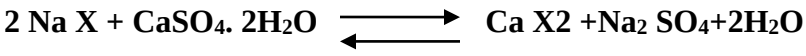
Reclamation of saline soils is done by applying excess water to the soil surface. Removal of salts by leaching may be accomplished either by continuous ponding of water on the soil surface or by intermittent leaching. Continuous ponding is only possible where water is available on demand. In Pakistan, generally intermittent leaching is practiced because water is supplied to farmers on a turn basis from canals (warabandi). No specific recommendation can be made for the amount of water required to reclaim saline soils. On an average 60-120 cm of water is the reclamation requirement depending on the salt concentration, soil texture and structure. Rice can be successfully grown in a partially submerged condition on moderately saline soils.

Reclamation of Sodic and Saline Sodic Soils

Reclamation of saline sodic and sodic soils is more difficult, time consuming and expensive than that of saline soils. It involves not only leaching of soluble salts but also the replacement of exchangeable Na with Ca and the improvement of physical properties of the soil. The reclamation of saline sodic and sodic soils requires good soil and water management, ample water for leaching, suitable chemical amendments and selection of salt-tolerant crops. Reclamation of saline sodic and sodic soils without the application of amendments is extremely slow, wasteful of water and time consuming.

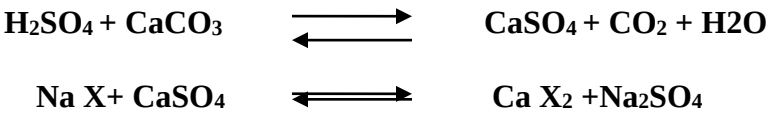
Soil Amendments

a. Gypsum ($CaSO_4.2H_2O$) is considered the best amendment and the cheapest source of calcium in Pakistan. When it is added to the sodic soil, following chemical reaction occurs and soil is reclaimed.



$$\mathbf{2\ Na\ X + CaSO_4.\ 2H_2O \rightleftharpoons Ca\ X2 + Na_2\ SO_4 + 2H_2O}$$

b. Sulphuric acid (H_2SO_4) may also be used in place of gypsum in calcareous sodic soils. In this case, chemical reaction will be as under:



$$\mathbf{H_2SO_4 + CaCO_3 \rightleftharpoons CaSO_4 + CO_2 + H2O}$$

$$\mathbf{Na\ X + CaSO_4 \rightleftharpoons Ca\ X_2 + Na_2SO_4}$$

Precaution: Sulphuric acid should be added in water

Comparison of Amendments Equivalent Quantity:

Quantity of H_2SO_4 eq to Gypsum	=	0.57
Quantity of H_2SO_3 eq to Gypsum	=	0.47
Quantity of HCl eq to Gypsum	=	1.71

Post Reclamation Strategies:

- First crop should preferably be Rice.
- Selection of high delta salt tolerant crop sequence.
- Inclusion of green manuring crops in crop rotation.
- Addition of organic material.
- Frequent soil testing.
- Fallowing should completely be avoided.