

MANAGEMENT OF IRRIGATION-INDUCED SALT-AFFECTED SOILS

The value and yield of soils with high contents of salts are significantly reduced, causing severe socioeconomic and environmental problems in the long term. The accumulation of salts from improper soil and water management is a serious problem worldwide. The global cost of irrigation-induced salinity is equivalent to an estimated US$11 billion per year.

To stop the loss of arable land due to salt accumulation it is necessary to use appropriate soil and water management practices. Recognizing the symptoms of salt-affected soils in time may save costly reclamation efforts and further land losses.

ORIGINS OF IRRIGATION-INDUCED SALT-AFFECTED SOILS

Primary salinization occurs naturally where the soil parent material is rich in soluble salts, or in the presence of a shallow saline groundwater table. In arid and semiarid regions, where rainfall is insufficient to leach soluble salts from the soil, or where drainage is restricted, soils with high concentrations of salts (“salt-affected soils”) may be formed. Several geochemical processes can also result in salt-affected soil formation. When an excess of sodium is involved in the salinization process this is referred to as sodification.

Secondary salinization occurs when significant amounts of water are provided by irrigation, with no adequate provision of drainage for the leaching and removal of salts, resulting in the soils becoming salty and unproductive. Salt-affected soils reduce both the ability of crops to take up water and the availability of micronutrients. They also concentrate ions toxic to plants and may degrade the soil structure.

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The salt balance of soils can be significantly affected through improper soil and water management, for example through:

1. improper irrigation schemes management, including:
   - insufficient water application;
   - insufficient drainage;
   - irrigation at low efficiency (where most of the water leaks into the groundwater) and/or over-irrigation contribute to a high water table, increasing drainage requirements and causing waterlogging and salinity build-up in many irrigation projects of the world;
   - irrigation with saline or marginal quality water, which may be caused by intrusion of saline water into fresh water aquifers in coastal zones due to overpumping.
2. poor land levelling - small differences in elevation may result in salinization of the lower parts, as the water table is closer to the surface and is subject to greater evaporation;
3. dry season fallow practices in the presence of a shallow water table;
4. misuse of heavy machinery leading to soil compaction and poor drainage;
5. excessive leaching during reclamation techniques on land with insufficient drainage;
6. use of improper cropping patterns and rotations;
7. chemical contamination. *e.g.* as a result of intensive farming, where large amounts of mineral fertilizers have been applied over a long period of time.

TYPES OF SALT-AFFECTED SOILS

Salt-affected soils may contain an excess of water-soluble salts (saline soils), excess exchangeable sodium (sodic soils) or both an excess of salts and exchangeable sodium (saline-sodic soils). Within each soil classification a range of physical and chemical characteristics can be observed **(Table 1)**.

HOW ARE SALINIZATION AND SODIFICATION PREVENTED?

The main strategy for controlling irrigation-induced salinity is to implement good farming practices, water-use efficiency measures and drainage facilities:

1. good soil management:
   - maintenance of satisfactory fertility levels, pH and structure of soils to encourage growth of high yielding crops;
   - maximization of soil surface cover, *e.g.* use of multiple crop species;
   - mulching exposed ground to help retain soil moisture and reduce erosion;

TABLE 1 **Classification of salt-affected soils.**

Salt-affected Soil Classification	Electrical Conductivity[1] ($dS\ m^{-1}$)	Soil pH	Sodium Adsorption Ratio[2]	Soil Physical Condition
Saline	> 4.0	< 8.5	< 13	Normal
Saline-sodic	> 4.0	< 8.5	> 13	Normal
Sodic	< 4.0	> 8.5	> 13	Poor

[1] The ability of the soil solution to carry an electrical current. Measured by passing an electrical current through a soil solution extracted from a saturated soil sample. The lower the salt content, the lower the electrical conductivity and the less the effect on plant growth.

[2] A relation between soluble sodium (Na^+) and soluble divalent cations (Ca^{2+} and Mg^{2+}) which can be used to predict the exchangeable sodium fraction of soil equilibrated with a given solution.

Adapted from Brady, N.C., 2002, *The Nature and Properties of Soils*, New Jersey, USA, Prentice Hall.

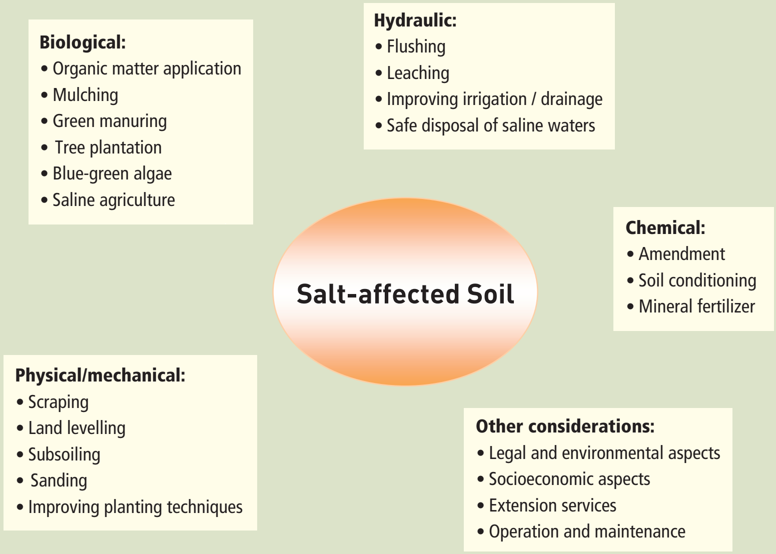

FIGURE 1 **Integrated management practices for the reclamation of salt-affected soils.**

- crop selection, e.g. use of deep-rooted plants to maximise water extraction;
- using crop rotation, minimum tillage, minimum fallow periods.

2. good water management:
- efficient irrigation of crops, soil moisture monitoring and accurate determination of water requirements;
- choice of appropriate drainage according to the situation:
  a. surface drainage systems to collect and control water entering and/or leaving the irrigation site;
  b. subsurface drainage systems to control a shallow water table below the crop root zone;
  c. biodrainage: the use of vegetation to control water fluxes in the landscape through evapotranspiration.
- adequate disposal of drainage waters to avoid contamination of receiving waters and the environment.

HOW TO RECOGNISE SALT-AFFECTED SOILS:

- delayed/reduced germination
- stunted growth
- foliar damage
- salt crusts
- waterlogging

Saline soils tend to inhibit germination and emergence of cereal grains. Herbaceous crops can appear bluish green under severe salt stress, while leaf-tip burn and die off of older leaves occur in cereals. Patterns of growth in salt-affected fields are usually poor. Excess soluble salts often crystallize on the surface of fallow fields and a thin, patchy salt crust forms. In sodic soils a brownish-black crust sometimes forms on the surface due to dispersion of soil organic matter. The presence of a permanent or seasonal high water table is often a sign of saline or sodic soils. Where salinity is suspected, confirmation of the type and extent of the problem should be obtained by laboratory analysis.

RECLAMATION OF SALT-AFFECTED SOILS

Management of salt-affected soils requires a combination of agronomic practices and socioeconomic considerations **(Fig. 1)**. For instance, reclamation of saline soils may begin with the provision of effective drainage and good quality irrigation water to lower the levels of soluble salts. Some saline-sodic and sodic soils can be reclaimed by adding gypsum ($CaSO_4$), followed by leaching out of the sodium.

Where salinity is increasing as a problem on an irrigated farm, it may be necessary to select crop varieties that have a greater tolerance to salts **(Table 2)**.

Moreover, where the land is severely salt-affected, it may be more economical to take it out of production and address the negative environmental impacts.

TABLE 2 **Tolerance of some crops to saline conditions. Salinity expressed as electrical conductivity.**

Sensitive (0-4 dS m^{-1})	Moderately Tolerant (4-6 dS m^{-1})	Tolerant (6-8 dS m^{-1})	Highly Tolerant (8-12 dS m^{-1})
Almond	Corn	Fig	Barley
Bean	Grain Sorghum	Oats	Cotton
Clover	Lettuce	Pomegranate	Olive
Onion	Soybean	Sunflower	Rye
Potato	Tomato	Wheat	Wheatgrass

Adapted from Brady, N.C., 2002, *The Nature and Properties of Soils*, New Jersey, USA, Prentice Hall.

CONCLUSIONS

Soil salinization significantly limits crop production and consequently has negative effects on food security. The consequences are damaging in both socioeconomic and environmental terms. Prevention and reclamation of salt-affected soils require an integrated management approach, including consideration of socioeconomic aspects, monitoring & maintenance of irrigation schemes and reuse and/or safe disposal of drainage water. Implementation of efficient irrigation and drainage systems and good farming practices can prevent and, in some cases, reverse salinization. If appropriate management practices are not applied in time, it may be necessary to take the land out of production altogether.

For further information on integrated soil management practices please consult:

SPUSH

Global Network on Integrated Soil Management for Sustainable Use of Salt-affected Soils

Land and Plant Nutrition Management Service (AGLL), FAO.

Web site: http://www.fao.org/ag/agl/agll/spush/intro.htm

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