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Soil Salinization: A Global Challenge and The Path to Recovery

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Introduction

Soil salinization is the accumulatio of water-soluble salts or their ions in the soil above a threshold of toxicity which has negative impact on soil physical, chemical and biological properties as a result the yield of crop decreases. Agricultural land is becoming more salinized and sodified due to unsustainable farming methods, water scarcity, and climate change. By the end of the twenty-first century, it is predicted that 23% of dryland would have increased on earth, with 80 percent of this increase occurring in developing countries. Currently, 27 percent of the world's population (1.9 billion people) suffer from severe water shortages; by 2050, this percentage is predicted to increase to 42–68 percent (2.7–3.2 billion people) (FAO, 2023). According to these predictions, the number of soils affected by salt will increase dramatically over the next few decades, necessitating a change in farming practices to sustain production in the face of water scarcity and salinity.

What makes soil salinization a critical issue?

Soil salinization is a huge problem as it results in the following

- Toxic to plant and may degrade soil structure.
- Reduce ability for uptake of water by crops.
- Reduce soil fertility and availability of micronutrients.
- Reduces crop yield.
- Causes an annual loss of $31 million in agriculture productivity.
- 1 to 2 million-hectare of farmland are unusable annually due to soil salinization (Hopmans *et al*., 2021)

Main Causes of Soil Salinization

The process by which water-soluble salts like magnesium, calcium, potassium, sodium, chlorides etc accumulate in the soil and have the potential to damage ecosystems, crops, and

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the environment is known as soil salinization. Soil salinization can be caused by a variety of natural and man-made factors.

Primary – Environmental	Secondary – Anthropogenic
These are natural sources of mineral elements that contributing to salinity. They are • Salty parental material • Salty groundwater • Sea/tidal water • Windblown salt particles • Climate (arid or semi-arid climate) • Floods from salt affected area	These are caused by human interventions in natural environment that causes salt problems in soil. They are • Poor drainage • Inappropriate fertilizer • Improper waste disposal • Inappropriate use of wastewater • Inappropriate land use change

Improved Measures of Soil Salinization

Improved measures to manage and mitigate soil salinization focus on a combination of preventive strategies, remediation techniques, and sustainable agricultural practices. For effective managing of soil salinization, various measures are given below

1. Irrigation and drainage measures
2. Agronomic measures
3. Chemical measures
4. Biological measure

1. Irrigation and Drainage Measures

Irrigation and drainage methods reduce salt by water salt dynamics both at surface and underground (Zhang *et al*., 2012).

The three main types of drainage methods are

a. Horizontal drainage system

A horizontal drainage system is a network of holes drilled into the ground to lower the water table and relieve groundwater pressure. It is a type of drainage system in which water is supplied in horizontal manner, they are three types

- Open drain- it's a type of drainage system where water surface is exposed.
- Pipe drain- it's a type of drainage system in which drain pipes are installed in the soil below the plough layer.

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- Mole drain- these are unlined tunnels that improve soil permeability and drain excess water with low cost.

b. Vertical drainage system

A vertical drainage system is a network of drains that helps remove excess water from soil, which can reduce the risk of soil instability and settlement. It consists of a network of tube wells to lower the water table, including pumps and surface drains to cope with the excess water

- Lowe the water table
- Supplement irrigation

c. Dry drainage system

It is an alternative to artificial methods for those area where the coat of drainage services and adverse environment impact exceed the expected benefits.

2. Agronomic Measures

Farmers may adopt different types of agronomic techniques to minimize the negative impact of salinization on yield of the main crop. These include mechanical means and cropping system management.

a. Mechanical means

It includes different types of mechanical activities like

- **land leveling**- it refers to moving earth in irrigated fields to improve surface slope and smoothness,
- **Deep ploughing and sub-soiling**- these can improve soil permeability of the root zone and may even break the low permeability layer of a soil profile in some areas, promoting the leaching soil salt from root zone area,
- **Scraping**- salt on the soil surface can be scraped and removed manually or mechanically to avoid further effects on plant which results in decreasing the salt accumulation in the root zone.

b. Cropping system management

There are some types of cropping practices that have positive effect in combating salinity

- **Crop rotation**,
- **Intercropping**,

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- ❖ C**rop residue management**
- ❖ **Land use conversions** which help to have a positive effect in combating salinity.

3. Chemical Measures

Different chemical measures used for the reclamation of salty soils can be grouped into two categories.

a. Organic amendments

These can mitigate issues caused by excess salts or sodium without supplemental irrigation. e.g., biochar and compost.

Biochar

- It is the carbon-rich material produced from organic feedstock under certain thermal combustion with limited oxygen. Biochar can be made from a variety of organic wastes, including municipal solid waste and agricultural waste.
- It increases the water holding capacity, soil biological activity, and decrease soil bulk density. (Ali *et al*., 2017).

b. Inorganic amendments

Those which are rich in calcium requires water to activate the chemical processes of reducing sodium level or leaching salt the root zone.

e.g., gypsum, fly ash and zeolite.

Gypsum

- Gypsum is the most effective amendment for reclaiming sodic soil due to its substantial Ca2+ supply capacity.
- Ca2+ replaces Na+ from the soil colloids, and leaches Na2So4 deeper into the soil profile.
- A combination of gypsum and mineral langbeinite resulted in significant reduction of soil exchangeable Na+, and improved soil saturated hydraulic conductivity. (Bello *et al*., 2021)

These organic and inorganic amendments will improve soil physical, chemical and biological properties (Mukhopadhyay *et al.*, 2021)

4. Biological Measures

The amelioration measures of soil salinization in biological measures includes breeding, halophytes domestication and microorganism application.

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a. Breeding for salt-tolerance crops

- Breeding crops to be more salt-tolerance can be a valuable technique to tackle soil salinization.
- Halophytes are plant that are salt tolerant while plants that are sensitive to salt are called glycophytes.
- The salt tolerance of halophytes is often accompanied by succulence and improved capacity to maintain increased water content (Isayenkov, 2019)

b. Domestication of halophytes

- Besides their capillarity to thrive under extremely saline conditions, halophytes also have great potential in rehabilitating saline soils. These is based on the fact that these plants can extract salt from the soil and accumulate in their tissues. Mangroves are best example.

c. Application of beneficial microorganisms

- Microorganisms contribute to soil ecosystem change by regulating nutrient cycling, decomposing organic matter, suppressing soil-born plant disease, determining soil structure and supporting plant productivity.
- When properly managed, microbial communities can also contribute to the recovery of the degraded ecosystem and system health (Moqsud, 2021).

Conclusion

Soil salinization is a critical global issue that threatens agricultural productivity, environmental health, and food security. Caused by both natural factors, like arid climates and salty groundwater, and human activities such as poor irrigation practices and land mismanagement, it leads to reduced soil fertility, impaired water uptake by plants, and diminished crop yields. As climate change and water scarcity worsen, the extent of salinized land is expected to rise, particularly in developing countries. Effective solutions to combat soil salinization include improved irrigation and drainage systems, agronomic practices like crop rotation and land levelling, the use of organic and inorganic soil amendments, and the development of salt-tolerant crops. Biological measures, such as the domestication of halophytes and the application of beneficial microorganisms, also offer promising avenues for restoring soil health. By adopting a combination of these strategies, it is possible to mitigate the negative impacts of salinization, restore soil fertility, and ensure long-term agricultural sustainability, thereby safeguarding food production for future generations.

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