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Unveiling the Hidden Threat: Understanding and Tackling Salt Affected Soils

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As we strive to feed a growing global population, the health of our soils becomes increasingly crucial. However, lurking beneath the surface lies a silent threat to agricultural productivity: salt-affected soils. These soils, laden with elevated levels of soluble salts, pose a significant challenge to farmers worldwide. From the arid plains of Rajasthan to the lush fields of Punjab, salt-affected soils affect millions of hectares of land in India alone. Salts generally originate from native soil and irrigation water. Salt-affected soils normally occur in arid and semi-arid regions where rainfall is insufficient to leach salts from/out of the root zone. Salt problems, however, are not restricted to arid or semi-arid regions. In India, the extent of salt-affected soils is staggering. According to recent estimates, approximately 6.73 million hectares of land are affected by salinity and alkalinity, out of which 3.77 M ha are sodic while 2.96 M ha are saline soils, representing around 2% of the country's total geographical area.

Salt affected soils

Salt-affected soils are defined as those soils that have been adversely modified for the growth of most crop plants by the presence of soluble salts, with or without high amounts of exchangeable sodium (Soil Science Society of America, 1997). Common Ions responsible for this problem are sodium (Na^{+}), calcium ($Ca2^{+}$), magnesium ($Mg2^{+}$), chloride (Cl^{-}), sulfate ($SO4^{2-}$), carbonate (CO_3^{2-}), and, bicarbonate ($HCO3^{-}$) in high concentrations and in some cases boron (B) and nitrate ($NO3^{-}$) (Bernstein, 1975).

Causes of salt-affected soil

Salt-affected soils are a result of both natural processes and human activities.

- Accumulation of salt for arid and semi-arid areas
- Weathering of parental rocks
- Deposition of oceanic salts
- Agricultural land - Irrigation
- Poor water management
- High evaporation

Characteristics of salt-affected soil

- **Electrical Conductivity (EC):** Salt-affected soils have high EC values due to the presence of soluble salts, which can be measured to assess soil salinity.
- **Exchangeable Sodium Percentage (ESP):** Sodic soils are characterized by a high ESP, indicating the predominance of exchangeable sodium ions.
- **pH:** Saline soils typically have a neutral to alkaline pH, while sodic soils tend to be alkaline due to the presence of sodium carbonate.
- **Soil Structure**: High levels of salts and sodium can deteriorate soil structure, leading to reduced water infiltration, increased soil erosion, and poor root penetration.
- **Plant Growth**: Salt-affected soils inhibit plant growth by causing osmotic stress, ion toxicity, and nutrient imbalances

Table 1: Characteristics of salt affected soil

Salt Affected Type	EC (Ds/M)	ESP (%)	Sodium Absorption Ratio	PH
Saline	> 4	<15	<13	<8.0
Sodic	<4	>15	>13	8.5-10.5
Saline-Sodic	>4	>15	variable	>8.5

Types of salt-affected soil

Saline Soil Sodic Soil Saline-Alkali Soil

Saline soil

Saline soil contains a sufficient number of soluble salts to affect the crop growth but not containing a sufficient amount of exchangeable Na to alter the soil properties appreciably. Saline soils have high concentrations of soluble salts, mainly NaCl, which are prevalent in regions with limited rainfall and high evaporation rates. They are also known as white alkali soils or solon chalks. These soils lack structural B horizon and contain very little organic matter (<1%).

Causes of saline soils

- **Natural processes**, including mineral weathering, erosion, and salt deposition from water bodies, can lead to the formation of saline soils.
- **Irrigation with Saline Water**: Excessive or low-quality irrigation water with excessive salt levels can cause soil salt buildup.
- **Poor drainage** causes salt accumulation by preventing excess salts from draining out of the soil profile.
- **Deforestation and land degradation** can expose underlying saline minerals, resulting in the formation of saline soils.

Characteristics of saline soils

- **High Electrical Conductivity (EC):** Saline soils have high EC values due to the presence of soluble salts, which can be measured to assess soil salinity levels.
- **White Crust Formation:** The Accumulation of salts on the soil surface can lead to the formation of a white crust, indicating high salt content.
- **Poor Soil Structure**: High levels of salts can degrade soil structure, leading to reduced water infiltration, increased soil erosion, and poor root penetration.
- **Alkaline pH:** Due to the presence of sodium carbonate and other alkaline salts.
- **Stunted Plant Growth:** Excessive soil salinity inhibits plant growth by causing osmotic stress, ion toxicity, and nutrient imbalances, resulting in stunted growth and reduced crop yields.

Management strategies for saline soils

- **Installing drainage systems**, including surface ditches or subsurface drains, can remove excess water and salts from the soil.
- **Leaching:** Using low-saline water can remove surplus salts from the root zone, lowering soil salinity levels.
- **Gypsum (calcium sulfate**) can improve soil structure and lower sodium levels in salty soils by replacing exchangeable sodium with calcium.
- **Selecting Salt-Tolerant Crops**: Using tolerant types can reduce the negative impact of soil salinity on agricultural productivity.
- **Organic mulching** can reduce soil evaporation, maintain moisture levels, and improve plant growth by mitigating the influence of soil salt.
- **Implementing integrated soil and water management methods**, such as crop rotation and cover cropping.

Effect of soil salinity

A) Morphological effects: Includes stunted development, uneven growth, deep green leaves, patchy appearance, and burning of leaves.

(B) Physiological effects: Physiological drought refers to plant wilting despite adequate moisture levels.

C) Biochemical effects: Reduced enzyme activity. Protein molecules are dehydrated, resulting in denatured protein

D) Nutritional effects: Nutrients have an antagonistic effect. Higher HCO_3 concentration leads to a lack of micronutrient cations including Fe, Mn, Zn, and Cu.

Sodic soil

- Sodic soils contain high levels of exchangeable sodium ions (Na^+).
- Excessive sodium can displace essential nutrients, degrade soil structure, and reduce soil fertility.
- They also known as Black Alkali soils, Solonetz and Slick-Spots

Causes of sodic soils

- **Irrigation with Sodium-Rich Water**: Continuous irrigation with water containing high levels of sodium, such as groundwater or recycled wastewater, can lead to the accumulation of sodium ions in the soil over time.
- **Weathering of Sodium-Rich Minerals**: Natural processes, including the weathering of sodium-rich minerals like feldspar and mica, can contribute to the development of sodic soils.
- **Deforestation and Soil Erosion**: Removal of vegetation cover and soil erosion can expose sodium-rich parent materials, leading to the formation of sodic soils.

Characteristics of sodic soils

- **High Exchangeable Sodium Percentage (ESP):** Indicating the dominance of sodium ions in the soil exchange complex.
- **Poor Soil Structure:** Excessive sodium can disperse soil particles, leading to the breakdown of soil aggregates and the formation of a dense, impermeable layer known as a hardpan.
- **Alkaline pH**: Due to the presence of sodium carbonate, which further exacerbates soil sodicity.
- **Low Infiltration Rate:** Poor soil structure and high clay content result in low water infiltration rates, leading to waterlogging and reduced plant root growth.
- **Nutrient Imbalance**: High levels of sodium can interfere with the uptake of essential nutrients by plants, leading to nutrient deficiencies and reduced crop yields.

Management strategies for sodic soils

- **Soil Reclamation**: Reclamation techniques such as gypsum application, which replaces exchangeable sodium with calcium, can improve soil structure and reduce sodicity
- **Improving Drainage:** Installing drainage systems, such as subsurface drains or tile drains, can help alleviate waterlogging and improve soil aeration.
- **Organic Matter Addition**: Incorporating organic matter into sodic soils can improve soil structure, increase water retention, and enhance nutrient availability.
- **Crop Rotation:** Rotating salt-tolerant crops with deep-rooted species can help break up hardpans and improve soil structure over time.
- **Ameliorating Compaction:** Mechanical methods such as deep plowing or subsoiling can help alleviate soil compaction and improve root penetration.

Saline sodic soils

Saline-alkali soils, also known as saline-alkaline soils or alkali saline soils, are a type of soil characterized by high levels of soluble salts and alkaline pH. These soils pose significant challenges to agriculture due to their adverse effects on soil fertility, plant growth, and water quality. Possesses blackish or dark brown color due to the formation of complex structures of Na & K with organic material

Calcareous soil

- Have a high content of Calcium carbonate and calcium oxide
- Calcareous soil develops from Limestone rock

Challenges and future threat of salt-affected soils

Climate change poses a looming threat, exacerbating soil salinity through rising temperatures and changing precipitation patterns. Technological innovations, such as remote sensing and precision agriculture, offer promising avenues for monitoring and managing salt-affected soils more effectively. However, widespread adoption of these technologies remains a challenge, particularly in resource-constrained agricultural regions.

Conclusion

Salt-affected soils represent a pressing issue for agricultural sustainability in India and beyond. As we strive to feed a growing global population, addressing the challenges posed by these soils is paramount. By adopting holistic management strategies, harnessing technological innovations, and implementing sound policies, we can mitigate the impact of salt-affected soils and ensure the long-term productivity and resilience of our agricultural systems.

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