SOIL SALINIZATION – CAUSES AND MANAGEMENT FOR SUSTAINABLE CROP PRODUCTION

Dr. V. K. Venugopal
Former Professor & Head
Department of Soil Science and Agricultural Chemistry College of Agriculture, Vellayani
Consultant, Digital University Kerala

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CENTRE FOR DIGITAL INNOVATION AND PRODUCT DEVELOPMENT
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Salinization

- Salt-affected soils occur in the arid and semiarid regions where evapotranspiration greatly exceeds precipitation and the products of weathering accumulate causing salinity or alkalinity
- A process by which there is build-up of salt in soil to such a level that impacts the agricultural production, environmental health, economy and quality of life.
- Involves a combination of processes like evaporation, salt precipitation, dissolution, salt transport, ion exchange etc.

Desertification

- A type of land degradation in drylands in which biological productivity is lost due to natural processes or over exploitation by human activities, climate change and areas become increasingly arid

Global distribution

- **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) estimates of 2018 show about 190 million acres are completely lost**

- **150 million acres are damaged**
- **2.5 billion acres are impacted by salinization**

Indian Scenario

- **Present area of 6.73 million ha of salt-affected soils would almost treble to 20 million ha by 2050**
- **Expansion in irrigated area and use of poor quality irrigation water to fulfil the food and other livelihood requirements of an increasing population are factors**

Extent of salt-affected soils in India ('000 ha)

Sr. No.	State	Saline soils	Sodic soils	Total
1.	Gujarat	1680.570	541.430	2222.000
2.	Uttar Pradesh	21.989	1346.971	1368.960
3.	Maharashtra	184.089	422.670	606.759
4.	West Bengal	441.272	0.000	441.272
5.	Rajasthan	195.571	179.371	374.942
6.	Tamil Nadu	13.231	354.784	368.015
7.	Andhra Pradesh	77.598	196.609	274.207
8.	Haryana	49.157	183.399	232.556
9.	Bihar	47.301	105.852	153.153
10.	Punjab	0.000	151.717	151.717
11.	Karnataka	1.893	148.136	150.029
12.	Orissa	147.138	0.000	147.138
13.	Madhya Pradesh	0.000	139.720	139.720
14.	Andaman & Nicobar Island	77.000	0.000	77.000
15.	Kerala	20.000	0.000	20.000
Total	2956.809	3770.659	6727.468	

Source: NRSA (National Remote Sensing Agency) Associates (1996) and Adapted from Arora and Sharma (2017).

Categories of Salt-affected soils - saline, sodic and saline-sodic

Characteristics of saline soils

- EC_e > 4 dS /m, ESP < 15% and pH < 8.5.
- Salt concentration 0.2 %
- SAR ≤ 13%
- Dominant cations Ca2+, Mg2+, K+
- Dominant Anions Cl^{-1}, SO_4^{-1},NO_3^-
- Soil structure – Flocculated
- Infiltration and drainage – Good
- Nomenclature Solenchalk (White Alkali)

Characteristics of Sodic /Alkali soils

- ECe < 4 dS/m, ESP > 15% and pH > 8.5.
- Salt concentration 0.2 %
- SAR > 15%
- Dominant cations Na+
- Dominant Anions CO^2_3 HCO_3^-
- Soil structure - Deflocculated
- Infiltration and drainage- Poor
- Nomenclature Solenetz (Black Alkali)

Causes of salinity

Natural processes of soil salinization (primary salinization)

- Weathering of rock minerals or sediments with high salt content releases soluble ions
- Low rainfall and leaching in arid regions leads to accumulation of salts
- Low-lying areas with high groundwater table and locked topography favor salinization.

Fossil salt

- Fossil salt deposits (marine and lacustrine) are also responsible for salinization in arid regions.
- Fossil salts get dissolved under water storage or water transmission structures causing salinization

Salinization in coastal lands and river beds

- Ingression of sea-water along the coast increases
- Salt-laden winds and rains along sea coasts carry oceanic salts sufficient to cause salinization
- Coastal regions are also exposed to the risk of progressive salinization of land due to processes like storms, cyclones, tidal surges, flooding etc.
- Salts brought down from the upstream by rivers and their deposition along with alluvial materials

Anthropogenic reasons of soil salinization (secondary salinization)

- Land clearing for cultivation and replacement of perennial vegetation with annual crops cause salts to accumulate by seepage process.
- Less permeable subsoil layers may intercept the percolating water passing through saline sediments resulting in lateral seepage, and salinization of low lying areas

Faulty irrigation

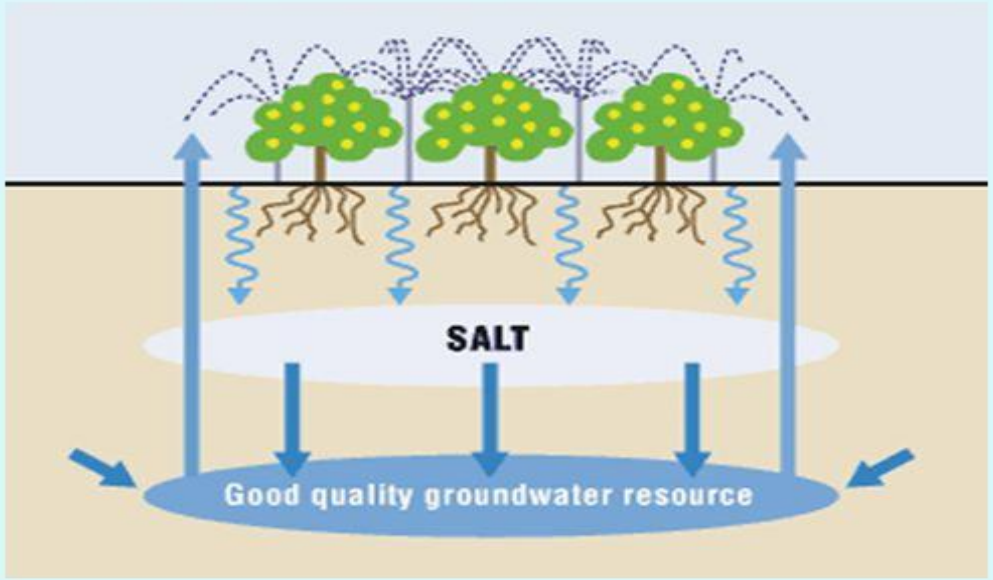
- Indiscriminate use of brackish and saline irrigation water, poor drainage conditions, rising water tables etc., lead to secondary salinization
- Even with good quality water over a period of time in the Improper soil-water-crop management practices cause salinization.
- Over extraction of groundwater brings salts to soil surface where they get precipitated by evaporation of water

Canal water seepage

- Serious problem leading to rise in water table and salinity development along the banks of canals

Salinization of Irrigated Soil

- Irrigation water soaks through the soil area where the plant roots grow, adding to the existing water.
- The additional irrigation water causes the underground water-table to rise, bringing salt to the surface.
- When the irrigated area dries & the underground water table recedes, salt is left on the surface soil.
- Each time the area is irrigated this salinity process is repeated.



- Over-use of chemical fertilizers and soil amendments (lime and gypsum) may also lead to soil salinization.
- Use of sewage sludge or untreated sewage effluent, dumping of industrial brine into the soil etc. cause salinization and heavy metals contamination

Indicators of salinity

- Noted visually by analyzing the soil surface, speed of water infiltration, and vegetation state
- As salinization proceeds, signs get more severe as slight whitening on surface and distinct salt crystals
- indirect indicators of extra salt concentration, poorer water quality or animal behavior when livestock refuses to drink water
- Damp areas and waterlogging;

Reference

Souvik Sam,Sagar Maitra and Rahui Adhikari,2022, Saline soil and its Reclamation process in India: A Review. Indian Journal of Natural Sciences. Vol.13(72)

Severely surface encrusted saline soil with salt crystals

Saline resistant plants surviving in the field

- increased water level in furrows;
- Bare soils (where plants fail to grow due to salinization);
- Appearance of salt tolerant species
- White or dark circles around water bodies

Soil salinity detection and measurement

- Apart from visual estimation more reliable methods to quantify salinity include
- Measurement of electrical conductivity to assess salt concentration
- Electrical conductivity is expressed as EC_e dS/m (Saturation extract conductivity)
- Exchangeable Sodium Percentage (ESP) me/100g
- Sodium Adsorption Ratio. (SAR)

Salinity and plant growth

- Decreases productivity of crops, affects soil physicochemical properties and ecological balance of the area.
- Impairs physiological, biochemical processes, seed germination, water and nutrient uptake, vegetative and reproductive development
- Causes ion toxicity, osmotic stress, nutritional imbalances or combination of all these factors
- Deficiency of (N, Ca, K, P, Fe, Zn) and oxidative stress on plants,
- Plant phosphorus uptake reduced by precipitation with Ca ions
- Elements, such as Na, Cl and B, have specific toxic effects on plants.
- Excessive accumulation of sodium in cell walls can rapidly lead to osmotic stress and death
- High salt levels in the soil can upset the nutrient balance and uptake
- Affects photosynthesis reduction in leaf area, chlorophyll content and stomatal conductance

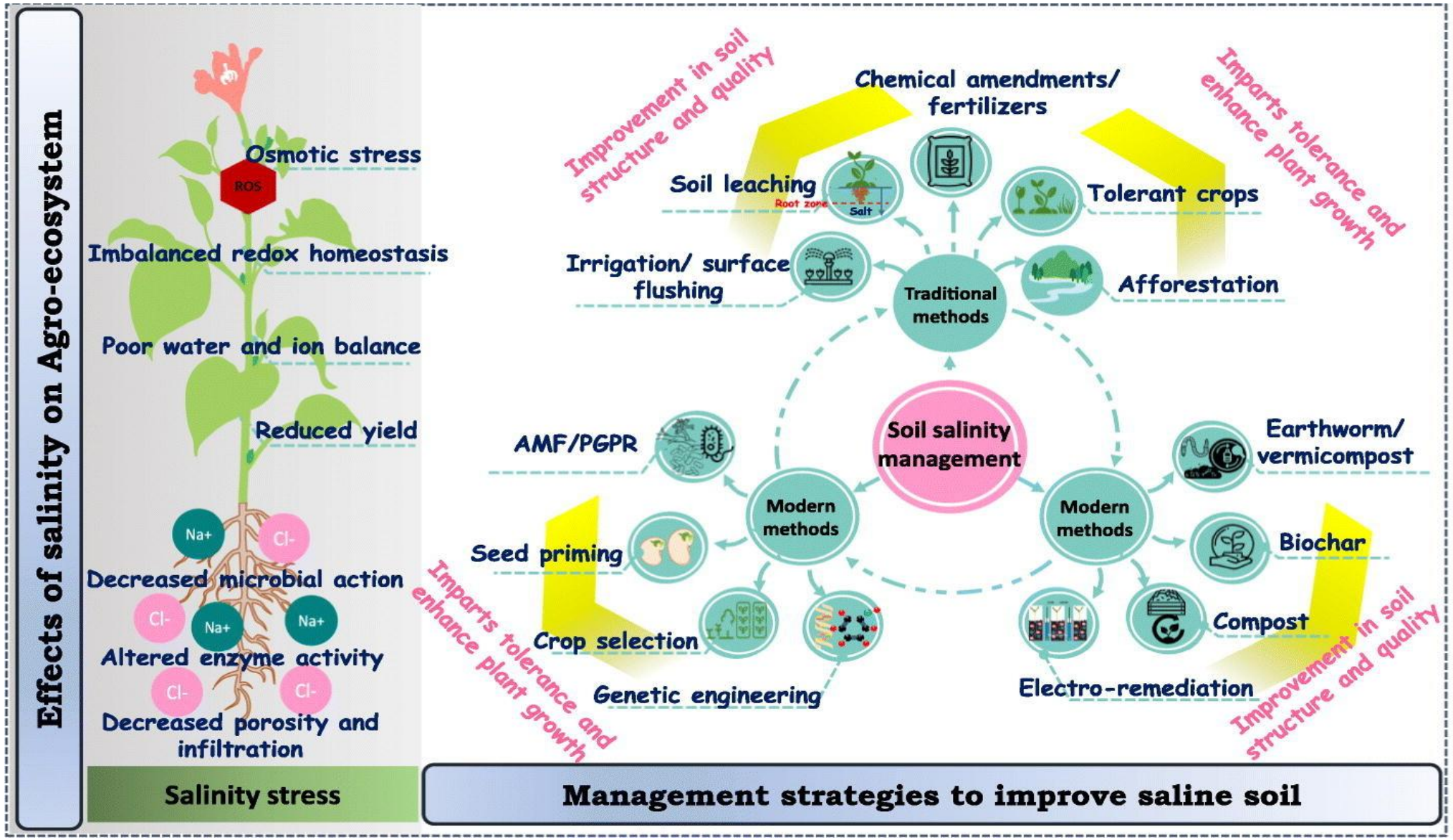
Strategies for reclamation of salt affected soils- CSSRI Technologies

Sodic soils

- **Gypsum-based alkali land reclamation technology and helps to replace sodium by calcium on exchange sites and the subsequent removal of exchanged sodium by the application of good quality water**

Saline soils

- **Subsurface drainage is an effective technological intervention to overcome the twin problems of waterlogging and salinity**
- **Sub-surface drainage network using concrete or PVC pipes with filters installed manually or mechanically at a particular spacing and depth below the soil surface,**
- **Drains out the excess water containing soluble salts**
- **Widely and successfully used in Haryana, Rajasthan, Gujarat, Punjab, Andhra Pradesh, Maharashtra, Madhya Pradesh and Karnataka**
- **The crops grown in the reclaimed saline soils exhibit high to very high increases in yield (45% in paddy, 111% in wheat and 215% in cotton)**
- **Rapid adoption of this technology is hindered by the higher initial establishment costs, operational difficulties, lack of community participation and the problems encountered in disposal of drainage effluents**


Effects of salinity on Agro-ecosystem
Osmotic stress
ROS
Imbalanced redox homeostasis
Poor water and ion balance
Reduced yield
Na+
Cl-
Decreased microbial action
Cl-
Na+
Na+
Altered enzyme activity
Cl-
Cl-
Decreased porosity and infiltration
Salinity stress
Improvement in soil structure and quality
Chemical amendments/ fertilizers
Imparts tolerance and enhance plant growth
Soil leaching
Root zone
Salt
Tolerant crops
Irrigation/ surface flushing
Traditional methods
Afforestation
Soil salinity management
AMF/PGPR
Modern methods
Modern methods
Earthworm/ vermicompost
Seed priming
Biochar
Imparts tolerance and enhance plant growth
Crop selection
Compost
Genetic engineering
Electro-remediation
Improvement in soil structure and quality
Management strategies to improve saline soil

Phytoremediation of Salt-affected Soils

- Salt leaching with fresh water has associated environmental problems in disposing leachate
- Reclamation of sodic soils require procuring large quantities of the costly chemical ameliorants Gypsum
- Use of salt tolerant trees, shrubs and grasses for cost-effective phytoremediation
- Cost effective and environmental-friendly method for restoration of degraded saline sodic soils
- Soils under tree cover showed improvement in physiochemical properties of soil, organic matter and biological properties and improvement in soil health.
- Number of tree species identified for both salt affected and sodic soils
- Commercial plantations of Agroforestry trees alleviate forage and fuel scarcities and aid carbon sequestration

Site specific management strategies have also been formulated

Coastal saline soils

- Water harvesting from dug out farm ponds, salt tolerant rice varieties, efficient rain water management and integrated rice-fish culture are popular
- For resource poor farmers' high yielding varieties have been released which show tolerance to high salt content and pH

• Alternate land use systems

- Number of salt tolerant agro-forestry and fruit trees, shrubs, grasses, medicinal and aromatic plants have been identified for commercial cultivation in salt-affected and sodic soils.
- Silvi-pastoral model has been found promising for sustained fuelwood and forage production in high pH soils for fuel and forage production
- A four year cycle of the tree and grass cover reclaims sodic soils to such an extent that normal agriculture with specific crops and agronomic practices can be taken up

Bio - drainage to combat waterlogging and secondary salinity

- Refers to the bio-energy driven, pumping out, of excess soil water and dissolved salts through rapid transpiration by the perennial trees
- Proven technology to prevent salinity build-up in canal commands areas tree species (Eucalyptus, popular, and bamboo) are raised in the beginning to prevent waterlogging and salinization
- Combined applications of bio-drainage and suitable land modifications are being explored to productively utilize the waterlogged salt affected soils

Saline Aquaculture:

- Degraded soil and water resources are put to profitable use by shrimp and fish farming
- Successfully being carried out in extreme saline environment in Panjab and Haryana

Multi enterprise Agriculture model

- Integrated multi-enterprise model consisting of diverse components field and horticultural crops, fishery, cattle, poultry and beekeeping is being practiced in extremely saline and waterlogged sodic soils of Uttar Pradesh, Gujarat, West Bengal
- ensures sustainable resource use efficiency, high and regular incomes and employment generation.

Resource conservation Technologies

- CSSRI, Karnal successfully demonstrated the efficacy of different technologies
- Zero tillage in wheat, direct seeded rice
- Residue incorporation and mulching
- Sprinkler irrigation- optimizes resource use by rice and wheat crops for sustained and profitable production and improves physico-chemical and biological properties of the soils

Way Forward

- **Globally, salinization is a major challenge to sustainable agricultural production and food security.**
- **Mismanagement of agricultural lands and overexploitation of water resources in arid climates have been highlighted as some of the major causes of soil salinization.**
- **While some of the approaches now implemented have successfully reduced the negative impact of salinity on crop cultivation and emerging approaches show promising initial results,**
- **Sustainable development, keeping in view the resources, technical expertise, infrastructure, and traditions of the country has to be the watch word**
- **Approaches like transgenes and genome editing can be beneficial, as they improve the physiology of the plants, and hence their performance under salinity conditions.**
- **Provision of plant genotypes with such genes will help the breeders to incorporate these traits into their own germplasm.**
- **Application of beneficial microbes and fertigation through drip irrigation as a participatory approach with farmers will keep the farming community to meet their requirements in food and agro-based products.**


Soil is our life,
conserve and save it
to celebrate this occasion of
World Soil Day.


Thank You