

24.

## Genesis, Characteristics, and Reclamation of saline soils

### Learning objectives

To study the genesis, characteristics and reclamation of saline soils

Saline soils are defined as soils having a conductivity of the saturation extract greater than 4  $\text{dS m}^{-1}$  and an exchangeable sodium percentage less than 15. The pH is usually less than 8.5. Formerly these soils were called white alkali soils because of surface crust of white salts.

### Relationship between $\text{EC}_{\text{SE}}$ and $\text{EC}_{1:2.5}$

| EC ( $\text{dS m}^{-1}$ ) |        |
|---------------------------|--------|
| Saturation extract        | 1: 2.5 |
| 4-8                       | 1-3    |
| 8-12                      | 3-8    |
| 12-16                     | 8-16   |

### Formation

The process by which the saline soil formed is called salinisation. Saline soils occur mostly in arid or semi arid regions. In arid regions saline soils occur not only because there is less rainfall available to leach and transport the salts but also because of high evaporation rates, which tend further to concentrate the salts in soils and in surface waters.

### Major production constraints

Presence of salts leads to alteration of osmotic potential of the soil solution. Consequently water intake by plants restricted and thereby nutrients uptake by plants are also reduced. In this soil due to high salt levels microbial activity is reduced. Specific ion effects on plants are also seen due to toxicity of ions like chloride, sulphate, etc.

## Management of saline soils

The reclamation of saline soils involves basically the removal of salts from the saline soil through the processes of leaching with water and drainage. Provision of lateral and main drainage channels of 60 cm deep and 45 cm wide and leaching of salts could reclaim the soils. Therefore, provision of adequate drainage system is a pre-requisite for any reclamation process. Sub-surface drainage is an effective tool for lowering the water table, removal of excess salts and prevention of secondary salinisation.

### ***Irrigation management***

Efficient water management leads to increased crop yield under saline soil condition. Proportional mixing of good quality (if available) water with saline water and then using for irrigation reduces the effect of salinity. Alternate furrow irrigation favours growth of plant than flooding. Drip, sprinkler and pitcher irrigation have been found to be more efficient than the conventional flood irrigation method since relatively lesser amount of water is used under these improved methods.

### ***Fertilizer management***

Addition of extra dose of nitrogen to the tune of 20-25% of recommended level will compensate the low availability of N in these soils. Addition of organic manures like, FYM, compost, etc helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition. Green manuring (Sunhemp, Daincha, Kolingi) and or green leaf manuring also counteracts the effects of salinity. Application of farm yard manure at 5 t ha<sup>-1</sup> at 10-15 days before transplanting in the case of paddy crop and before sowing in the case of garden land crops can alleviate the problems of salinity.

### ***Crop choice / Crop management***

Crops are to be chosen based on the soil salinity level. The relative salt tolerance of different crops is as follows:

#### **Relative tolerance of crops to salinity**

| <b>Plant species</b> | <b>Threshold salinity (dS m<sup>-1</sup>)</b> |
|----------------------|---|
| <b>Field crops</b>   |   |
| Cotton               | 7.7   |

|                   |     |
|-------------------|-----|
| Sugarbeet         | 7.0 |
| Sorghum           | 6.8 |
| Wheat             | 6.0 |
| Soybean           | 5.0 |
| Groundnut         | 3.2 |
| Rice              | 3.0 |
| Maize             | 1.7 |
| Sugarcane         | 1.7 |
| <b>Vegetables</b> |     |
| Tomato            | 2.5 |
| Cabbage           | 1.8 |
| Potato            | 1.7 |
| Onion             | 1.2 |
| Carrot            | 1.0 |
| <b>Fruits</b>     |     |
| Citrus            | 1.7 |

### ***Soil / cultural management***

Planting the seed in the centre of the raised bed / ridge may affect the germination as it is the spot of greatest salt accumulation. A better salinity control can be achieved by using sloping beds with seeds planted on the sloping side just above the water line. Alternate furrow irrigation is advantageous as the salts can be displaced beyond the single seed row. Application of straw and polythene mulch had been found to curtail the evaporation from soil surface resulting in the reduced salt concentration in the root zone profile within 30 days.

Management of saline soils becomes essential and unavoidable particularly in areas where both soil as well as irrigation water is saline in nature.

## Occurrence in India:

Extent and distribution of salt affected soils in India

| Sr. No. | State          | Saline soils<br>(ha) | Alkali soils<br>(ha) | Coastal saline soil<br>(ha) | Total<br>(ha)  |
|---------|----------------|----------------------|----------------------|-----------------------------|----------------|
| 1       | Andhra Pradesh | 0                    | 196609               | 77598                       | 274207         |
| 2       | A & N islands  | 0                    | 0                    | 77000                       | 77000          |
| 3       | Bihar          | 47301                | 105852               | 0                           | 153153         |
| 4       | Gujarat        | 1218255              | 541430               | 462315                      | 2222000        |
| 5       | Haryana        | 49157                | 183399               | 0                           | 232556         |
| 6       | J & K          | 0                    | 17500                | 0                           | 17500          |
| 7       | Karnataka      | 1307                 | 148136               | 586                         | 150029         |
| 8       | Kerala         | 0                    | 0                    | 20000                       | 20000          |
| 9       | Maharashtra    | 177093               | 422670               | 6996                        | 606759         |
| 10      | Madhya Pradesh | 0                    | 139720               | 0                           | 139720         |
| 11      | Orissa         | 0                    | 0                    | 147138                      | 147138         |
| 12      | Punjab         | 0                    | 151717               | 0                           | 151717         |
| 13      | Rajasthan      | 195571               | 179371               | 0                           | 374942         |
| 14      | Tamil Nadu     | 0                    | 354784               | 13231                       | 368015         |
| 15      | Uttar Pradesh  | 21989                | 1346971              | 0                           | 1368960        |
| 16      | West Bengal    | 0                    | 0                    | 441272                      | 441272         |
|         | <b>Total</b>   | <b>1710673</b>       | <b>3788159</b>       | <b>1246136</b>              | <b>6744968</b> |

Source : [www.cssri.org](http://www.cssri.org)

## Questions to Ponder

- 1)What is the relationship between salts and electrical conductivity?
- 2)What is the fate of leached out salt during saline soil reclamation?
- 3)What is the nutrient management in saline soil?
- 4)Where is saline soil predominant in India?Why? ?
- 5)What are halophytes?

25.

## Genesis, Characteristics, and Reclamation of sodic soils

### Learning objectives

To study the genesis, characteristics and reclamation of sodic soils

### Sodic soils - Definition

Alkali or sodic soil is defined as a soil having a conductivity of the saturation extract less than  $4 \text{ dS m}^{-1}$  and an exchangeable sodium percentage greater than 15. The pH is usually between 8.5 – 10.0.

Most alkali soils, particularly in the arid and semi-arid regions, contain  $\text{CaCO}_3$  in the profile in some form and constant hydrolysis of  $\text{CaCO}_3$  sustains the release of  $\text{OH}^-$  ions in soil solution. The  $\text{OH}^-$  ions so released result in the maintenance of higher pH in calcareous alkali soils than that in non – calcareous alkali soils.

### Expected loss of soil productivity due to ESP in different soils

| ESP     | Loss in productivity (%)                           |                            |
|---------|--|----------------------------|
|         | Alluvium derived soils<br>(Inceptisols / Alfisols) | Black soils<br>(Vertisols) |
| Up to 5 | Nil  | Up to 10                   |
| 5-15    | <10  | 10-25                      |
| 15-40   | 10-25  | 25-50                      |
| >40     | 25-50  | >50                        |

### Formation

Soil colloids adsorb and retain cations on their surfaces. Cation adsorption occurs as a consequence of the electrical charges at the surface of the soil colloids. While adsorbed cations are combined chemically with the soil colloids, they may be replaced by other cations that occur in the soil solution. Calcium and Magnesium are the principal cations found in the soil solution and on the

exchange complex of normal soils in arid regions. When excess soluble salts accumulate in these soils, sodium frequently becomes the dominant cation in the soil solution resulting alkali or sodic soils.

### **Major production constraints**

Excess exchangeable sodium in alkali soils affects both the physical and chemical properties of soils.

- a) Dispersion of soil colloids
- b) Specific ion effect

### **Reclamation of alkali / sodic soils**

#### **Physical Amelioration**

This is not actually removes sodium from exchange complex but improve physical condition of soil through improvement in infiltration and aeration. The commonly followed physical methods include

- Deep ploughing is adopted to break the hard pan developed at subsurface due to sodium and improving free-movement water. This also helps in improvement of aeration.
- Providing drainage is also practiced to improve aeration and to remove further accumulation of salts at root zone.
- Sand filling which reduces heaviness of the soil and increases capillary movements of water.
- Profile inversion – Inverting the soil benefits in improvement of physical condition of soil as that of deep ploughing.

#### **Chemical Amelioration**

Reclamation of alkali / sodic soils requires neutralization of alkalinity and replacement of most of the sodium ions from the soil – exchange complex by the more favourable calcium ions. This can be accomplished by the application of chemical amendments (the materials that directly or indirectly furnish or mobilize divalent cations, usually  $\text{Ca}^{2+}$  for the replacement of sodium from the exchange complex of the soil) followed by leaching to remove soluble salts and other reaction products. The chemical amendments can be broadly grouped as follows:

- ❖ **Direct Ca suppliers:** Gypsum, calcium carbonate, phospho-gypsum, etc.

❖ **Indirect Ca suppliers:** Elemental Sulphur, sulphuric acid, pyrites,  $\text{FeSO}_4$ , etc.

Among them gypsum is, by far, the most commonly used chemical amendment. Calcium carbonate is insoluble in nature which of no use in calcareous sodic soils (have already precipitated  $\text{CaCO}_3$ ) but can be used in non calcareous sodic soils (do not have precipitated  $\text{CaCO}_3$ ) since pH of this soils are low at surface and favouring solubilisation of  $\text{CaCO}_3$ . Some of indirect suppliers of Ca viz. Elemental sulphur, sulphuric acid, iron sulphate are also used for calcareous sodic soils. These materials on application solubilise the precipitated  $\text{CaCO}_3$  in sodic soils and releases Ca for reclamation.

### **Other sources**

#### ***Distillery spent wash***

Distillery spent wash is acidic (pH 3.8-4.2) with considerable quantity of magnesium. About 2 lakh litres of distillery spent wash can be added to an acre of sodic soil in summer months. Natural oxidation is induced for a period of six weeks with intermittent ploughing once in a month. In the second month (after 45-60 days) fresh water may be irrigated and drained. Such a treatment reduces the pH and exchangeable sodium percentage and increases the productivity of the sodic soil.

#### ***Distillery effluent***

Distillery effluent contains both macro and micronutrients. Because of its high salt content, it can be used for one time application to fallow lands, About 20 to 40 tonnes per ha of distillery effluent can be sprayed uniformly on the fallow land. It should not be allowed for complete drying over a period of 20 to 30 days. The effluent applied field has to be thoroughly ploughed two times for the oxidation and mineralization of organic matter. Then the crops can be cultivated in the effluent applied fields by conventional methods.

#### ***Pulp and paper mill effluents***

Pulp and paper effluents contain lot of dissolved solids and stabilized organic matter. The properly treated matter can safely be used for irrigation with appropriate amendments viz. pressmud @ 5 tonnes  $\text{ha}^{-1}$ , fortified pressmud @ 2.5 tonne  $\text{ha}^{-1}$  or daincha as in situ green manure.

The following crops and varieties were found to be suitable for cultivation in Tamil Nadu along with recommended doses of amendments viz. pressmud @ 5 tonnes ha<sup>-1</sup>, fortified pressmud @ 2.5 tonnes ha<sup>-1</sup> or daincha as in situ green manure (6.25 tonnes ha<sup>-1</sup>).

|              |  |
|--------------|--|
| Rice         | IR 20, TRY 1, CO 43                          |
| Maize        | CO 1   |
| Sunflower    | CO 2   |
| Groundnut    | TMV 2, TMV 7                                 |
| Soybean      | CO 1   |
| Sugarcane    | COC 92061, COC 671, COC 6304, COC 91064      |
| Fodder crops | Cumbu-Napier hybrid, Paragrass, Guinea grass |

Certain oil seed crops like gingelly and castor, pulses like greengram and blackgram were found to be sensitive for effluent irrigation.

### **Benefits**

- Application of gypsum, pressmud and pyrite increases the grain yield of rice grown in a sodic soil by 79, 81 and 69 % over control respectively. Pyrite was as effective as one third of gypsum, when applied on total S content basis.
- Gypsum alone enhanced the grain yield significantly by > 50 % over control. When the manures (Green manures, FYM) were added with gypsum further improvement in yield (15 %) was observed.
- An average yield improvement of > 50 % could be possible according to severity of the problem.

### **Crop choice**

Rice is preferred as first crop in alkali / sodic soil as it can grow under submergence, can tolerate fair extent of ESP and can influence several microbial processes in the soil. Rice-Wheat / Barley – *Sesbania*, rice-berseem are some of the rice based cropping sequences recommended for sodic soils during reclamation. Some of the lands where aerable cropping after reclamation is not economically feasible can be brought under different agroforestry systems like silviculture,



silvipasture etc. which can improve the physical and chemical properties of the soil along with additional return on long-term basis. Some grasses like *Bracharia mutica* (Para grass) and *Cynodon dactylon* (Bermuda grass) etc. had been reported to produce 50% yield at ESP level above 30.

The sodicity tolerance ratings of different crops is as follows

#### Relative tolerance of crops to sodicity

| ESP (range*) | Crop  |
|--------------|---|
| 2-10         | Deciduous fruits, nuts, citrus, avocado       |
| 10-15        | Safflower, blackgram, peas, lentil, pigeonpea |
| 16-20        | Chichpea, soybean                             |
| 20-25        | Clover, groundnut, cowpea, pearl millet       |
| 25-30        | Linseed, garlic, clusterbean                  |
| 30-50        | Oats, mustard, cotton, wheat, tomatoes        |
| 50-60        | Beets, barley, sesbania                       |
| 60-70        | Rice  |

\*Relative yields are only 50% of the potential in respective sodicity ranges.

#### Relative tolerance of fruit trees to sodicity

| Tolerance to sodicity | ESP   | Trees  |
|-----------------------|-------|--|
| High                  | 40-50 | Ber, tamarind, sapota, wood apple, date palm |
| Medium                | 30-40 | Pomegranate                                  |
| Low                   | 20-30 | Guava, lemon, grape                          |
| Sensitive             | 20    | Mango, jack fruit, banana                    |

#### Benefits

Sodic soil reclamation through afforestation is a slow process measuring about 20-30 % during 9 years with a better efficacy of *A. indica* than *Pongamia pinnata*.

## Saline-alkali/ sodic soils

Saline-alkali / sodic soil is defined as a soil having a conductivity of the saturation extract greater than 4 dS m<sup>-1</sup> and an exchangeable sodium percentage greater than 15. The pH is variable and usually above 8.5 depending on the relative amounts of exchangeable sodium and soluble salts. When soils dominated by exchangeable sodium, the pH will be more than 8.5 and when soils dominated by soluble salts, the pH will be less than 8.5.

### Formation

These soils form as a result of the combined processes of salinization and alkalization. If the excess soluble salts of these soils are leached downward, the properties of these soils may change markedly and become similar to those of sodic soil.

### Management of saline alkali soils

The reclamation / management practices recommended for the reclamation of sodic soil can be followed for the management of saline – sodic soil.

### Occurrence in India:

#### Extent and distribution of sodic soils in India

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|---------|----------------|-------------------|
| 1       | Andhra Pradesh | 196609            |
| 2       | Bihar          | 105852            |
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| 10      | Rajasthan      | 179371            |
| 11      | Tamil Nadu     | 354784            |
| 12      | Uttar Pradesh  | 1346971           |
|         | <b>Total</b>   | <b>3788159</b>    |

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## **References**

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## **Questions to Ponder**

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