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Reclamation of Saline and Sodic Soil: The State of Review

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Abstract

Soil is an essential resource which plays an important role in environment, economic and social functions. Soils possessing high quality not only fulfil food and fiber demands but also support to establish natural ecosystem, enhancing air and water quality. Land degradation caused due to salinization and sodification of soils has become a universal problem. It also reduces the per capita availability of land resources. Sodic and saline-sodic soils possess poor physical properties and fertility problems that adversely affect the growth and yield of most crops. The negative water balance in soil leading to salinization and sodification is caused by less precipitation, unmanaged use of water resources and Excessive evaporation. Sodic soils are very difficult and costly to reclaim compared to saline soils. Sodic soils require the addition of suitable amendments to replace adsorbed sodium at the cation exchange sites by calcium. Sodification and salinization affects the water holding capacity, nutrient availability, hydraulic conductivity, water uptake by the plants, root penetration and seedling germination. The use of gypsum with biological amendments proved to be more beneficial in reclaiming the sodic and saline-sodic soils than gypsum alone.
Keyword- Harmful Effects, Land Degradation, Reclamation, Saline Soil, Sodic Soil

I. INTRODUCTION

Soil and water are the essential resources for sustaining life. With the haphazardly growing population, these resources are being degraded on a large scale. Owing to this alarming situation, there emerges need to manage these resources judiciously so as to ensure long term sustainability. Many developing countries including India faces great menace towards the social, economic and political stability which may increase rapidly in the future. The serious problem of land degradation is soil degradation caused due to salinization and sodification of soils and has become a universal problem. It is estimated that 1.5 billion hectare of lands, all over the world are salt affected [03]. These salt affected soils affect agricultural productivity and expansion. Soil is an essential resource which plays an important role in environment, economic and social functions. It is non-renewable resource. Soils possessing high quality not only fulfil food and fibre demands but also support to establish natural ecosystem, enhancing air and water quality.

Out of (World's) total geographical area of 329 Mha, 175 Mha is considered salt affected in which alkali soils and saline soils including coastal areas account for 3.6 Mha and 5.5 Mha respectively [03]. Loss of organic matter, soil erosion, salinization, urbanization, compaction, water logging, reduction in biodiversity, nutrient imbalance, deterioration with heavy metals and pesticides are major factors affecting Indian soils. The impact of human activities such as irrigation on large scale, excessive use of chemical fertilizers and pesticides, overgrazing and deforestation has resulted in the increase of soil degradation. Thus we have to develop and implement technologies for soil management to overcome these great challenges that improve quality of soil as well as plant productivity.

A. Background

India's geographical area is 2.4 % of the world's area, supporting about 16.7% of the world's population and livestock about 17.2 % [03]. Out of the total land area in the country 162 mha (49.2%) is arable, 141 Mha (42.9%) is net sown, 69 Mha (20.8%) is under forest/ woodland and 11 Mha (33%) is under permanent pastures [03]. The availability of land per capita has decreased sharply from 0.48ha in 1951 to 0.20 ha in 1981 and 0.15 ha in 2000 and to be further decreased to 0.12 by 2025 [03]. In India, the salt affected soils are revealed in the states of Madhya Pradesh, Karnataka, Rajasthan, Maharashtra, Andhra Pradesh, West Bengal, Tamil Nadu and Gujarat. Salinity and sodicity are widening over large areas of cultivated fertile lands with the additional canal irrigation approach. Land degradation and desertification are further contributing towards reducing per capita availability of land resources.

II. DIFFERENCE BETWEEN SALINE AND SODIC SOILS

A. Saline Soil

It is also known as white kallar soil and thur soil by the engineers [06]. In these soils the concentration of soluble salts is excess because of presence of the sulphates, chlorides and carbonates of sodium, calcium and magnesium. When the water containing soluble salts is used for the irrigation, the salts reach the surface where water evaporates leaving the salts behind. NaCl and Na_2SO_4 are water soluble salts. The influence of saline soils is mainly on the uncultivated lands where no crop is grown over a longer period of time. In these soils due to percolation there is downward movement of dissolved salts. In saline soils the electrical conductivity (EC_e)of saturated soil extract is more than 4 decisiemens /meter (ds/m), PH less than 8.5 and exchangeable sodium percentage (ESP) less than 15. Saline soils are easy to reclaim simply by applying heavy irrigation, provided that the soil has good drainage[06].

In the field the diagnosis of affected soils can be done by following visual characteristics as below:

- During dry period when the soil moisture movement is upward the soil surface is covered with white fuzzy salt.
- The water permeability rate is higher.
- Decreases seedling germination, patches develop on crop, poor and complete failure of crop is observed in severely affected areas.

B. Sodic Soil

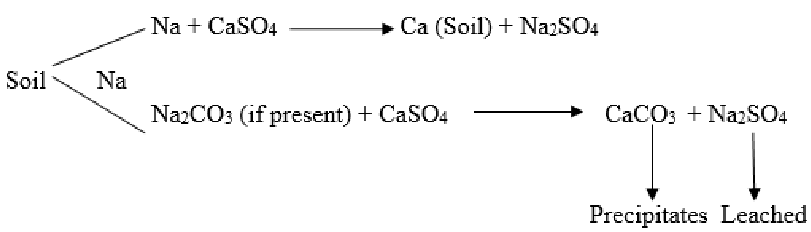
In sodic soils, sodium level (Na^+) adsorbed at the cation exchange sites is sufficiently high. In these soils the presence of sodium carbonate is superior. The use of gypsum is the most effective way to deal with the problem of these soils [06]. Soil sodicity is responsible for degradation of soil structure, which is known as soil dispersion. In these soils, the pH is more than 8.5, the exchangeable sodium percentage (ESP) is greater than 15, EC_e is below 4 ds/m[06]. Due to the adsorption of excessive sodium at the negative charges of clay particles, the forces holding clay particles together are greatly weakened. When wet, sodium clay particles break into the smaller soil aggregates. During dry condition, sodium clay particles settle down in dense layers, clogging the soil pores. The impaired permeability and high sodium content, make alkali soils difficult and expensive to reclaim. Poor soil structure affects the seed germination, soil ploughing and plant root growth. Sodic soils are prone to wind and water erosion because of poor physical structure than saline soils.

Under field conditions the following symptoms will be seen:

- During summer the surface is covered by white salt, which often shows dark black colour on wetting. Due to this characteristic, they are usually called "black alkali soils".
- When the soil is cultivated slightly wet, it is sticky.
- On drying shallow cracks are developed at the surface and soil becomes very hard and compact. Lumps become excessively hard and difficult to make suitable tilth for sowing seeds.
- The water does not move down quickly and remains on the surface in a muddy condition for a long period, because of the low hydraulic conductivity.
- The grasses mainly of Sporobolous species grow, but they also die during summer.

1) Reaction Mechanism in Sodic Soils

The action of Ca salts is mainly through exchange reactions with sodium.



C. Saline-Sodic Soils

These are both saline and alkali occurring in various stages of transition. EC_e of these soils is more than 4 dS/m, exchangeable sodium percentage greater than 15 and pH less than 8.5 depending upon the relative amounts of exchangeable sodium and soluble salts. When soluble salts are leached downward, the pH will increase above 8.5, making the soils sodic. Accumulation of excess soluble salts may decrease pH to 8.5.

III. FACTORS RESPONSIBLE FOR SALINE AND ALKALI SOILS FORMATION

The saline/alkali soils are developed by any one or more of several reasons, as follows:

- In arid regions, where evaporation is higher than the precipitation, the soluble salts accumulates near the soil surface.

- In arid regions, the ground water usually contains considerable quantities of soluble salts. If it is used for irrigation it degrades the good soil. The extent of deterioration depends upon the salt content of irrigation water as well as on the nature of salts and type of soils on which the water is to be used. The sodium salts are more harmful compared to Calcium & Magnesium salts. As the well waters do not get tested by the farmers, the productivity of lands is lost if the irrigation with such waters is continued.
- Sometimes the salts may be introduced directly from chemical weathering of rocks.
- Increasing applications of water irrigation and seepage from canals and tanks raises the ground water level sufficiently to permit continuous accumulation of salts at the surface due to capillary action and evaporation. The accumulation rate of salts would be much faster, If the quality of the subsurface water is saline.
- Poor drainage is responsible for accumulation of the salts in the surface soil and prevents the leaching of salts down below the root zone. Many saline soils in arid areas are formed due to inadequate and impaired drainage.
- Soil salinization in the coastal area is due to the accumulation of salts from the inundated sea water. Irrigation water contains considerable concentration of soluble salts, particularly sodium salts which lead to salinity.

IV. HARMFUL EFFECTS

A. Saline Soils

The saline soil retards the plant growth primarily because of excessive salts in the soil solution. The plants cannot get enough water due to high osmotic pressure developed in the root zone which, prevent absorption of moisture and nutrients in adequate amounts. An excess of sodium ions also exerts antagonistic effect on the absorption of calcium and magnesium. In the presence of salts, a characteristic leaf- burn develops, leading even to the death of trees when harmful amounts of sodium or chloride accumulate.

B. Sodic Soils

Under alkali soil conditions, the degradation is not due to salt concentration as the conductivity of the soil solution is low. Soils containing considerable amounts of sodium are not flocculated. This hinders the movement of air and water through the soil. The absorption of sodium by soil clay and organic colloids causes dispersion of clay which results in degradation of soil structure. Poor soil structure reduces drainage, aeration and microbial activity.

C. Saline-Sodic soils

Under saline sodic conditions, the crop may suffer not only because of high salinity but also due to unfavorable effects of alkalinity on the nutrient availability.

V. RECLAMATION OF SALT AFFECTED SOILS

The basic principle of reclamation of saline soils involves the removal of excess salts to a desired level in the rooting zone. In case of sodic soils, the sodium has to be removed by adding suitable amendments, particularly gypsum and then improving drainage [02].

Y.P. Singh et al. (2013) [07] evaluated a field experiment to investigate the constraints on adoption and interventions of sodic soil reclamation technologies on pearlmillet – wheat crop sequence in canal command area. The trials were initiated in Galwa command area in North-Eastern part of Rajasthan state of India. The command area was severely affected by sodicity due to careless use of sodic ground water. Before beginning of trails, a survey was conducted on 64 farmers to assess farmers' response to land reclamation and to identify the constraints in adoption of reclamation technology. The result of survey revealed that 34.4% knew the sodic soil reclamation technology, 44 farmers had not adopted any practice of sodic soil reclamation. The soil selected from farmers' field was sandy loam in texture. The selected treatments for soil reclamation were as follows: T_1: control, T_2: Gypsum application as per gypsum requirement (GR) 25% + green manuring (GM), T_3: GR-50% + GM, T_4: GR-25% + GM + farm yard manure (FYM) @ 10 t/ha, T_5: GR-50% + GM + FYM @ 10 t/ha, T_6: Deep tillage (DP) + GR-25% + GM + FYM @ 10 t/ha and T_7: GR-50% + DP + GM + FYM @ 10 t/ha. The selected test crop was wheat in Rabi season and pearlmillet to be grown in coming Kharif season. After application of gypsum the sesbania seed was sown. The gypsum requirement varied from 3.75 to 5.46 t/ha. The source of water for irrigation was canal water having EC - 0.25dS/m, SAR - 0.92 in initial stage and underground water having EC-0.67dS/m, SAR - 14.7 after maturity stage. From the survey it was found that the main cause of non-adoption of land reclamation was lack of availability of good quality water (27.3% farmers), while, other factors responsible for lack of response to technology were lack of risk bearing capacity, undulated topography, fragmented holdings, lack of investment power and knowledge of reclamation and limited availability of gypsum.

Treatment	*EC (dS/m)*	*pH*	*ESP*	*OC (g/kg)*	*BD (mg/m³)*	*IR (cm/hr)*	*Available Nutrients*						
							N	*P*	*K*	*Zn*	*Fe*	*Cu*	*Mn*
T_1	0.53	8.95	32	1.5	1.51	0.32	121	10.7	246	0.43	5.2	0.28	2.0
T_2	0.32	8.29	20	1.9	1.50	1.06	150	12.7	278	0.53	5.3	0.28	2.2
T_3	0.33	8.02	16	1.4	1.48	1.23	173	13.4	286	0.67	5.5	0.29	2.3
T_4	0.31	8.24	17	1.7	1.49	1.65	164	13.5	290	0.70	5.6	0.30	2.3

T_5	0.34	8.03	13	1.8	1.48	1.82	187	15.4	294	0.74	5.8	0.31	2.5
T_6	0.27	8.08	14	1.8	1.46	2.85	184	14.9	290	0.70	5.7	0.31	2.4
T_7	0.28	7.81	11	1.9	1.46	3.15	193	16.8	315	0.76	5.9	0.33	2.6
CD at 5%	0.15	0.27	1.5	0.1	0.03	0.20	21	1.5	26	0.06	0.14	0.01	0.15

Table 1: Response of gypsum, deep tillage, green manuring and FYM on physico-chemical properties after harvest of wheat (2-year mean)

Thus it could be recommended from the results that the application of gypsum along with organic manure reduced soil sodicity, improved physico-chemical properties by reducing pH, ESP and Bulk density and consequently improved availability of nutrients in soil.

A.N.A. Haque et.al. (2015) [01] conducted a split-plot experiment to determine the effect of different combinations of Farm Yard Manure (FYM) and gypsum along with nitrogen levels. Five combinations of gypsum and FYM were prepared S_0: Control, S_1: FYM 5t/ha + Gypsum 140 kg/ha, S_2: FYM 5t/ha + Gypsum 210 kg/ha, S_3: Gypsum 210 kg/ha, S_4: FYM 5t/ha and following nitrogen levels were fixed N_1: 50 kgN/ha, N_2: 75 kgN/ha, N_3: 100 kgN/ha, N_4: 125 kgN/ha. Maximum grain yield and plant length was found in S_2 treatment. It was analyzed that combination of FYM and Gypsum may enhance physiological growth. Among different nitrogen levels the tallest plant was found from N_4 and lowest from N_1. The best treatment combination was recorded for S_2N_4 with respect to plant height as well as grain yield of Rice which was 109 cm and 4.39 t/ha respectively.

Sachin Jaiveersingh Yadav and Dr. Sunil Bhimrao Thakare (2015) [04] carried out a pot experiment to assess the potential of cow dung on the reclamation of saline soil. Soil samples were collected from five different locations as follows: (i) Market Yard Cut Section Position 2 (MYCS2), (ii) Coarse Soil Wanawadi Region (CSWR), (iii) College Campus Tekdi (CCT), (iv) Kondhwa Hospital (KH1), (v) Juhu Beach, Mumbai. 2 kg each soil samples were taken and placed in plastic pot, then in each sample salty water was added and finally 400 grams of cow dug was added and soil was tested for pH and electrical conductivity. In this experiment pH and electrical conductivity was tested before adding pollutants, after adding pollutants and after addition of cow dung. It was found that initially EC of the soil samples was very less but with the addition of salty water pH decreased while EC increased. After the addition of cow dung to the soil pH slightly increased while EC decreased rapidly. From the results it could be concluded that cow dung helps in reduction of salinity of moderately saline soil and also provided nutrients to the polluted soil which is the noble method for treatment of saline soil. The crop grown in soil which had used cow manure had not only high yield but also better quality grains as compared to artificial manure.

Samples from 5 different locations			
Initial pH and Electrical conductivity of soil			
Sr. No.	Sample Name	pH	EC(Ms/cm)
1	MYCS 2	7.02	0.058
2	CSWR	7.15	0.128
3	CCT	7.2	0.368
4	KH 1	7.84	0.147
5	JUHU BEACH	8.75	1.79

Table 2: Samples from 5 different locations with Initial pH and Electrical conductivity of soil

Samples from 5 different locations			
pH and Electrical conductivity of soil after addition of 200 ml salty water (1000ml dw + 100g salt)			
Sr. No.	Sample Name	pH	EC(Ms/cm)
1	MYCS 2	7.02	6.55
2	CSWR	7.26	5.59
3	CCT	7.11	6.07
4	KH 1	7.47	6.44
5	JUHU BEACH	8.4	7.51

Table 3: pH and Electrical Conductivity of Soil Samples with Salty Water Added

Samples from 5 different locations				
pH and Electrical conductivity of soil after addition of 400g cow dung				
Sr. No.	Sample Name	Cow dung added (g)	Ph	EC(Ms/cm)
1	MYCS 2	400	7.56	5.03
2	CSWR	400	7.35	5.21
3	CCT	400	7.31	5.43
4	KH 1	400	7.61	5.16
5	JUHU BEACH	400	8.56	5.23

Table 4: pH and Electrical conductivity of soil samples after addition of 400g cow dung

Sajal Roy et al. (2014) [05] conducted a pot experiment to examine the effects of commercial manure (CM) and poultry manure (PM) on the growth and nutrient content of Indian spinach (Basella alba) grown in saline soil. The study was carried out using 4 treatments with 3 replicates. The treatments used were T_1: Control, T_2: Soil + Commercial manure (10 t/ha), T_3: Soil + Poultry manure (10 t/ha), T_4: Soil + Poultry manure (5 t/ha) + Commercial manure (5 t/ha). 3 kg of soil was filled in each pot. Five seeds of Indian spinach were sown in each pot and maintained only one healthy plant. Results showed that the addition of organic manure to soil increased all the vegetative growth parameters such as fresh weight, leaf number, shoot and root length. Addition of organic manure increased concentrations of K, Ca, Mg, Fe and Mn in all parts of plants 2-3 folds as compared to control. The increased growth and nutrient content of plant suggested that the addition of organic manure at the rate of 10 t/ha could overcome or reduce the toxic effect of salinity and to obtain relatively good plant growth, yield, good quality and nutrient content.

VI. CONCLUSION

- Land degradation caused due to salinization and sodification of soils has become an universal problem.
- Land degradation and desertification are further contributing towards reducing per capita availability of land resources.
- Saline soils are easy to reclaim simply by applying heavy irrigation requiring that the soil has good drainage.
- Sodic soils are very difficult and costly to reclaim compared to saline soils. Sodic soils require the addition of suitable amendments to replace adsorbed sodium at the cation exchange sites by calcium.
- Sodification and salinization affects the water holding capacity, nutrient availability, hydraulic conductivity, water uptake by the plants, root penetration and seedling germination. It also affects physical and chemical properties of the soil.
- It was observed that gypsum is being extensively used as an amendment because of its low cost, ease of availability and handling. The combination of gypsum with biological amendments proved to be more beneficial than gypsum alone.

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