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Reclamation of Alkali Soils through Gypsum Technology

ICAR-CENTRAL SOIL SALINITY RESEARCH INSTITUTE

Karnal-132 001 (Haryana)

Alkali soils are characterized by variable EC_e, high pHs >8.2 and high exchangeable sodium percentage (ESP) >15. These soils have abundance of carbonates and bicarbonates of sodium, calcium, and magnesium as against chlorides and sulphates in the saline soils. High exchangeable sodium, high soil pH and low organic carbon cause swelling and dispersion of clay particles resulting in degradation of soil structure. It hardens soil surface, reduces infiltration and creates waterlogging after a rain event or irrigation resulting in reduced availability of water to plant, poor seed emergence, poor root development, poor drainage and other associated problems. While it adversely impacts the availability of several important nutrients/minerals, some elements may even prove toxic to the plants. As a result, crop yields are much lower in alkali soils than normal soils. Highly degraded lands present a desolate look with no signs of greenery.

Extent of problem

In India, 6.73 million ha (M ha) area has been characterized as salt-affected, out of which 3.77 M ha is alkali and the remaining 2.96 M ha is saline, threatening livelihood security of farming community. The distribution of alkali affected area among different states shown in Fig. 1 reveals that it is a serious problem across 11 states in India. Uttar Pradesh having the largest alkali area of 1.35 M ha accounts for 35.75 per cent of total alkali affected area followed by Gujarat (14.36%), Maharashtra (11.21%), Tamil Nadu (9.41%), Haryana (4.86%) and Punjab (4.02%). These six states are having about 80% of the total alkali lands of India.

Status of alkali land reclamation

Over the past few decades, chemical amelioration of alkali soils in Indo-Gangetic regions of Punjab, Haryana and Uttar Pradesh has been well standardized. With the support of World Bank, European Union and other developmental agencies, India has reclaimed 1.95 M ha of alkali lands (Fig. 2). Across states, Punjab has reclaimed largest area (0.80 M ha), followed by Uttar Pradesh (0.73 M ha), Haryana (0.35 M ha) and other states (0.07 M ha).

Production and monetary losses due to alkalinity

As per estimates of ICAR-CSSRI, every year, India loses 11.18 million tonnes (M t) of cereals, oilseeds, pulses and cash crops from 3.77 M ha alkali affected area, which is equivalent to the monetary loss of ₹ 1,50,000 million (₹ 15,000 Crores). State wise crop production losses shown in Fig. 3 and 4 reveal that Uttar Pradesh suffered production losses of 7.55 M t, around 68% of total losses at national level while Gujarat suffered production losses of 2.11 M t (nearly 19 % of total). Production losses in these two states are highest. In monetary terms, Uttar Pradesh incurred losses of ₹ 80,750 million followed by Gujarat of ₹ 51,490 million, Haryana of ₹ 6,550 million, Bihar of ₹ 5,060 million, Andhra Pradesh of ₹ 2,640 million and Tamil Nadu of ₹ 1,060 million.

Crop wise, cereals accounted highest production loss of 5.95 M t (53%), followed by cash crops, which also accounted significant production loss of 4.66 M t (42%) (Fig. 5). Among the crops, wheat, sugarcane, potato and rice suffered higher production losses of 3.60, 2.24, 1.80 and 1.60 M t, respectively. In monetary terms, cereals accounted the monetary loss of ₹ 79,000 million (i.e. 53% of total monetary losses) as shown in Fig. 6. Among cereals, wheat accounted the highest loss of ₹ 50,000 million (33%) followed by rice (₹ 19,000 million), pearl millet (₹ 5,000 million) and maize (₹ 4,000 million). This indicated that losses in cereal crops are more than half of the total losses. Cash crops suffered 35% (₹ 52,000 million) of total monetary losses, which is another major sufferer crop group after cereals. Among cash crops, share towards monetary losses for cotton and potato is ₹ 27,000 and ₹ 19,000 million, respectively, out of total monetary losses of ₹ 1,50,000 million. The share towards monetary losses for oilseeds is ₹ 11,000 million (7%) in which groundnut (₹ 5,000 million) and rapeseed and mustard (₹ 4,000 million) are the major crops. The share of pulses in the total monetary losses is ₹ 8,000 million (5%), the major crops being bengal gram (₹ 4,000 million) and pigeon pea (₹ 2,000 million). Among the crops, wheat, sugarcane, potato and rice suffered highest monetary losses due to alkalinity. Apparently, if the entire affected area is reclaimed through reclamation technology developed by ICAR-CSSRI, it will add annually 11.18 M t of farm production in India.

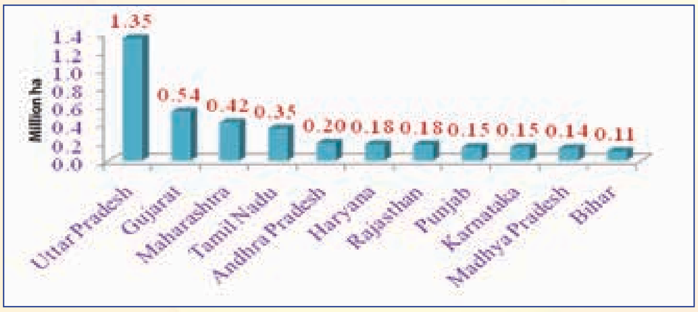

Fig. 1. State-wise distribution of alkali affected area

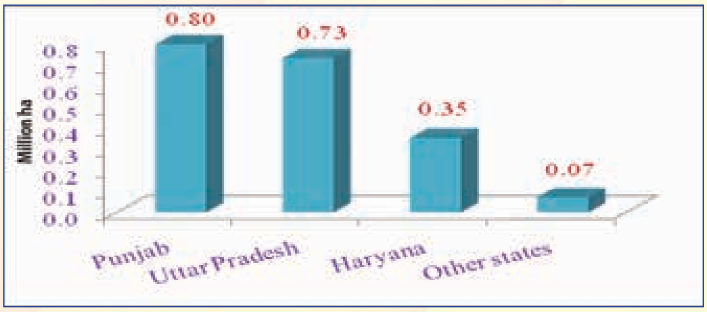

Fig. 2. Status of alkali land reclamation

Fig. 3. State-wise annual production losses due to alkalinity

Fig. 4. State-wise annual monetary losses due to alkalinity

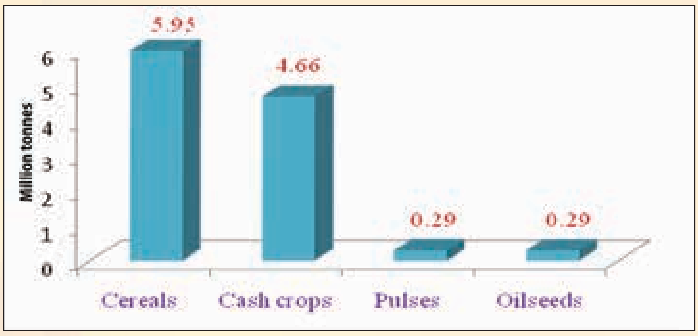

Fig. 5. Crop category-wise annual production losses due to alkalinity

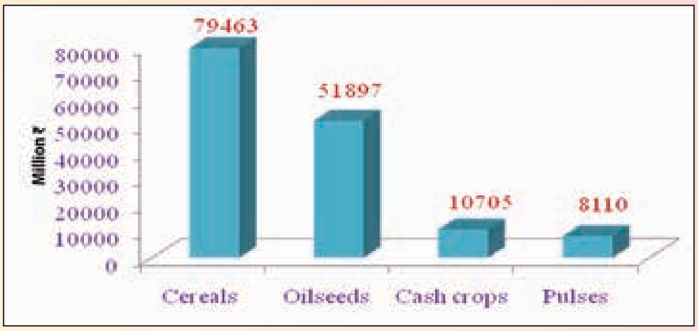

Fig. 6. Crop category-wise annual monetary losses due to alkalinity

Technology in brief

Reclamation of alkali soils requires the removal of exchangeable sodium and its replacement by calcium. This is accomplished by the application of gypsum or any other chemical amendment including several industrial wastes such as phospho-gypsum, distillery spent wash (DSW), etc. The following steps need to be executed to reclaim alkali soils.

1. **Soil sample collection :** Collect the soil samples upto 15 cm depth from the land to be reclamined for testing to know the soil pH. Gypsum is recommended based on the soil pH value.
2. **Land development :** The reclamation process is initiated by proper land levelling providing strong bunds on all sides of the farm to control ingress of water from the adjoining unreclaimed areas. The on-farm development works including farm layout with irrigation and drainage channels should be completed by early summer before the on-set of rains.
3. **Gypsum requirement :** Although the amount of amendment to be applied, is based on soil analysis, as a thumb rule, 12-15 tonnes of gypsum per hectare (50% of gypsum requirement of 0-15 cm soil as per soil analysis) is sufficient enough to reclaim upper 15 cm soil layer of a highly deteriorated soil (pH as high as 10.7) for successfully growing rice-wheat crops in rotation. The dose can be reduced to half, if 10-15 t/ha FYM is applied along with gypsum or salt tolerant rice and wheat varieties are used in the first 3 years of cultivation.
4. **Gypsum application and leaching :** The amendment is uniformly spread in the whole field and thoroughly mixed within 10 cm top soil layer, followed by ponding of irrigation/ rain water for about 7-10 days to promote leaching and create conducive environment for ionic reactions at soil exchange complex.
5. **Crop cultivation and management :** After leaching the excess water, land is properly cultivated and fertilized. As far as possible, reclamation should start with rice as the first crop. Rice is transplanted with puddling, ensuring 3 to 4 seedlings per hill and maintaining 15 to 20 cm distance between the hills. Seedlings, raised in normal/ good soil nursery should be preferred for use. The normal crop management practices should be followed. Submerged condition is to be maintained during rice crop. Wheat or berseem is the best option to continue the reclamation process during rabi season. Recommended crop varieties should be planted at the appropriate time. It is desirable to go in for a green-manure crop during summer. It improves soil physical conditions and also saves about 60-70 kg/ha of nitrogen in the following rice crop.

   Light and frequent irrigations to wheat crop, keeping total quantity of irrigation water same, are recommended to avoid stagnation of standing water.

Efficient, balanced and integrated nutrient management is an integral part of reclamation of alkali lands. Therefore, the following recommendations should be practiced to sustain productivity during and after reclamation.

- These soils are highly deficient in organic matter and Nitrogen. During the first few years after reclamation, crops are fertilized with about 25% more Nitrogen compared to recommended dose for normal soil. Split application of Nitrogen through urea (1/3rd as basal, 1/3rd each at 21 and 45 days crop growth) should be given. In rice, basal dose of urea should be applied under pre-submerged conditions to reduce ammonia volatilization losses and to enhance Nitrogen use efficiency.
- Apply 25 to 40 kg Zinc Sulphate per hectare to rice for first few years and then it should be applied on soil test basis.
- Farmyard manure, organic residues and green manures help in increasing the productivity. It is extremely important to integrate use of organic resources along with chemical amendments.
- Initially, alkali soils are high in available phosphorus. However, both rice and wheat require phosphorus fertilization @ 22 kg P/ha after 4-5 years to sustain productivity and to maintain soil fertility as available phosphorus in soil reduces to critical soil test value of 12 kg/ha.

Fig. 7. Alkali Soils Reclamation Steps

(a) Soil sampling (b) Land development (c) Gypsum application (d) Ponding of water and leaching (e) Rice transplanting (f) Rice-wheat crop rotation

Table 1. Annual contribution of reclaimed alkali lands to national food security in Uttar Pradesh

Particulars	Slightly sodic	Moderately sodic	Severely sodic	Total
Total land reclaimed (ha) till 2015	73197	182993	475781	731970
Cropped land under cereal production (ha)	71798	179496	466689	717982
Additional paddy production (M t)	0.12	0.57	1.82	2.51
Additional economic value-paddy (₹ million)	1832	8277	26391	36500
Food security-rice (million persons)	1.62	7.30	23.26	32.17
Additional wheat production (M t)	0.05	0.56	1.28	1.90
Additional economic value-wheat (₹ million)	698	8251	18609	27557
Food security-wheat (million persons)	0.53	6.29	14.18	21.00
Total additional food grain contribution (M t)	0.13	0.94	2.47	4.42
Contribution to food grain production (%)	3	21	56	100

Investment cost

In India, gypsum is the major soil amendment used to reclaim alkali soils. The cost for reclamation depends on quantity of gypsum required for reclamation. The quantity depends on pH or ESP of soil, alkalinity tolerance and rooting depth of crop to be grown. ICAR-CSSRI estimates reveal that the capital investment of about ₹ 76,000 per ha is required to reclaim alkali lands. The gypsum cost is the major item (57%) of cost followed by farm development cost including a bore well for each 4 ha area (27%) in total reclamation cost. Labour cost for soil amendment application, irrigation and flushing of salts and other miscellaneous items require around 16% of total investment cost.

Economic feasibility

Investment on alkali land reclamation involves short to medium gestation period. The economic feasibility analysis assuming 12 percent opportunity cost of capital revealed that the benefit-cost ratios varied from 1.34 to 2.47. The internal rates of return varied between 18% to 67% and payback period varied from 2 to 3 years.

Benefits of gypsum technology

Presently, major thrust of alkali soil reclamation is in Uttar Pradesh under World Bank assisted project following technology developed by ICAR-CSSRI. The state has reclaimed 0.73 M ha of alkali land by 2015 (Table 1). The severely affected lands, designated as Class C lands, constituted the highest around 65%, followed by moderately affected lands (25%) and slightly affected lands (10%). Horticultural lands constitute 0.2% of total reclaimed land. The highest additional paddy production was obtained from severely affected lands (3.9 t ha^{-1}) followed by moderately affected lands (3.18 t ha^{-1}) and slightly affected lands (1.76 t ha^{-1}). The reclaimed land produced 2.51 M t of additional paddy per annum. In monetary terms, it contributed ₹ 36,500 million. The highest additional wheat production was obtained from moderately affected lands (3.17 t ha^{-1}) followed by severely affected lands (2.75 t ha^{-1}) and slightly affected lands (0.67 t ha^{-1}). The reclaimed land produced 1.90 M t of additional wheat per annum. The reclaimed alkali lands produced 4.42 M t of additional food grains per annum in Uttar Pradesh alone and contributed around 2% to the India's total food grain production. The severely affected lands contributed highest additional food grain production of 56% to the total food grain production followed by moderately affected lands (21%) and slightly affected lands (3%). The additional production of paddy and wheat provided food security to 32.17 million people.

The benefits of land reclamation from 7,31,970 ha of Uttar Pradesh were not limited to direct benefits to the farming community but spanned across sectors benefitting the society as a whole. Transactions of farm input and output related agri-business industries were benefitted as a whole. Alkali land reclamation program contributed (Table 2) highest business transaction in food grain agri-business sector annually (₹ 60,754 million) and accounted for about 71% of the total contribution. It generated additional employment of 116 million person-days (₹ 14,479 million) per annum, being the next major contributor accounting for about 17% of the total. The land reclamation generated large business opportunities to other agri-business sectors like seed (₹ 4311 million), fertilizers (₹ 5375 million) and pesticides (₹ 940 million).

Table 2. Impact of alkali land reclamation on agri-business sector in Uttar Pradesh

Business Sectors	Value (₹ Million)
Employment	14,479
Seed	4,311
Fertilizer	5,375
Food grains	60,754
Pesticides	940
Total	85,895

Way forward

The reclamation process of alkali soil was initiated from Punjab and Haryana in 1970s, which was later extended to Uttar Pradesh with World Bank aided project, with technological package developed by ICAR-CSSRI. The execution of the projects was done by the land reclamation corporations of the respective states and other government departments. Around 1.95 M ha alkali land has been reclaimed adding 15 -16 M t of food grains to national food basket. The gypsum technology is well tested and validated under agro-climatic conditions of the country. Reclamation of entire alkali affected area would further add around 12 M t of food grains to the national pool.

For further information, please contact

Director

ICAR-Central Soil Salinity Research Institute, Karnal-132001, Haryana

Email: director.cssri@icar.gov.in, Website: www.cssri.org

Compilation: PC Sharma, K Thimmappa, MJ Kaledhonkar and SK Chaudhari