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Reclamation of Waterlogged Saline Soils through Subsurface Drainage Technology

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Waterlogging and soil salinity are major problems associated with land degradation in irrigated agriculture and are adversely affecting a portion of utilized irrigation potential of major and medium irrigation projects in India. The rising water table, a consequence of excessive deep percolation losses from irrigation fields and/or seepage from irrigation networks results in waterlogging in root zone leading to build-up of soluble salts causing twin problems of waterlogging and soil salinity simultaneously. As a result, plants face anaerobic conditions in root zone limiting aeration along with salinity stress. In waterlogged saline soils, water table remains within 1.5-2.0 m from the soil surface and soils are saline with EC_e more than 4 dS m^{-1} at 25 ^{o}C, pH_s less than 8.2 and an ESP less than 15. These soils are often found in irrigation commands of arid, semiarid and sub-humid coastal regions. However, there are saline soils without waterlogging and have been developed due to irrigation with saline groundwater. These soils fulfil above mentioned characteristics except waterlogging as the depth to water table may be deeper than 3 m. These soils have abundance of chlorides and sulphates of sodium, calcium and magnesium; are generally flocculated showing little signs of structural degradation; have high infiltration rate but water availability to plants is adversely affected due to osmotic stress that results in physiological drought. Excess salts impact the availability of nutrients/minerals and some of the elements may even be present in toxic concentrations. As a result, the crop yields are significantly less in saline than normal soils.

Extent of problem

Extent of saline lands in India is estimated by ICAR-CSSRI as 2.95 million ha (M ha). This estimate does not segregate waterlogging associated salinity and salinity due to groundwater irrigation. State wise distribution of saline soils in India (Fig. 1) reveals that salinity is a serious problem across 13 states of the country with Gujarat having largest area of 1.68 M ha (56.84%) followed by West Bengal (14.92%), Rajasthan (6.61%) and Maharashtra (6.23%).

Status of saline land reclamation

A number of pilot scale manually laid subsurface drainage (SSD) projects, undertaken by ICAR-CSSRI during 1980s, have slowly paved the way for mechanically installed large projects in the states of Haryana, Rajasthan, Maharashtra, Karnataka, Gujarat, Punjab and Andhra Pradesh. Implementation of large mechanically installed subsurface drainage projects has increased exponentially during the past 10 years with provision of Government funding under schemes like CADA, RKVY and others. So far, about 66,500 ha waterlogged saline soils have been reclaimed with SSD in India resulting in significant increase in cropping intensity and crop yields improving the socio-economic status of the farmers (Table 1).

Fig. 1. State wise distribution of saline areas

Table 1: An approximation of area covered by subsurface drainage in different states under Govt. schemes

State	Irrigation command	Area (ha)
Haryana	Western Yamuna Canal, Bhakra Canal	10,000
Rajasthan	Chambal, Indira Gandhi Nahar Pariyojana	16,500
Maharashtra	Lift irrigation systyem of Krishna river; Neera canal command, uncommanded	3,500*
Karnataka	Upper Krishna, Tungabhadra, Malprabha, Ghatprabha	25,000*
Punjab	Sirhind Canal (South West Punjab)	2,500
Manual (small projects in different states)	Andhra Pradesh (NagarjunaSagar, Krishna Western Delta); Gujarat (MahiKadana, UkaiKakrapar); Kerala (Acid sulphate soils); Assam (Tea gardens), Madhya Pradesh	3,000
Total		60,500

* In addition to the above Govt. supported projects, SSD has been installed in more than 3,000 ha area each in Maharashtra and Karnataka by local farmers without Govt. support.

Production and monetary losses due to salinity

ICAR-CSSRI estimates reveal that the crop production loss due to salinity at the national level is 5.66 million tonnes (M t), accounting for the annual monetary loss of ₹ 80,000 million (₹ 8,000 Crores). State wise distribution of these losses (Fig. 2 and 3) revealed that Gujarat suffered the highest production losses (2.72 M t) followed by Maharashtra (0.92 M t), West Bengal (0.89 M t) and Andhra Pradesh (0.40 M t). Accordingly, Gujarat suffered the highest monetary loss of ₹ 49,000 million followed by West Bengal (₹ 12,000 million), Maharashtra (₹ 5,000 million), Andhra Pradesh (₹ 5,000 million), Rajasthan (₹ 4,000 million), Odisha (₹ 3,000 million) and Haryana (₹ 1,000 million). The production losses in pulses are highest in Gujarat (0.08 M t) followed by Rajasthan (0.06 M t), West Bengal (0.04 M t), Maharashtra (0.03 M t) and Andhra Pradesh (0.01 M t). In oilseeds, Gujarat accounted for highest production losses of 0.52 M t, West Bengal (0.03 M t) followed by Rajasthan and Maharashtra each accounted 0.01 M t.

Crop wise analysis revealed that cash crops (2.48 M t) and cereals (2.35 M t) account for nearly 85% loss amongst the total crop production losses due to salinity, whereas, oilseeds (0.59 M t) and pulses (0.24 M t) contribute nearly 15% losses (Fig. 4). Among the crops, sugarcane (1,791 M t) and rice (1.41 M t) suffered higher production losses. In monetary values, cereals accounted the highest monetary loss of ₹ 30,230 million (Fig. 5), which is 38% of the total monetary losses. Among cereals, rice accounted for the monetary loss of ₹ 17,000 million (21%) followed by wheat (₹ 7,000 million) and maize (₹ 1,000 million). Contribution of oilseeds to monetary losses is ₹ 23,000 million (29%) with groundnut (₹ 20,000 million) being the major contributor followed by rapeseed and mustard (₹ 2,000 million). The cash crops contributed 25% (₹ 20,000 million) to the total monetary losses, which is another major contributor after cereals.

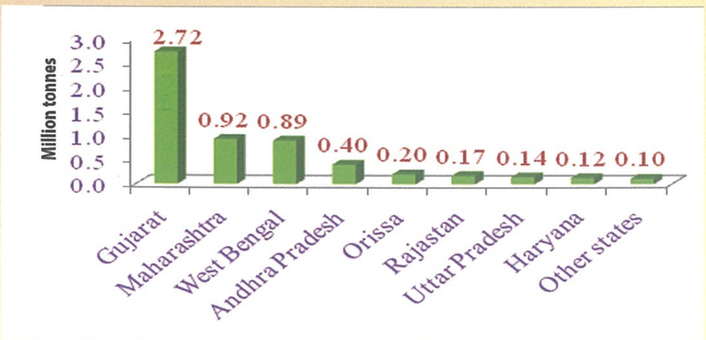

Fig. 2. State-wise annual production losses due to salinity

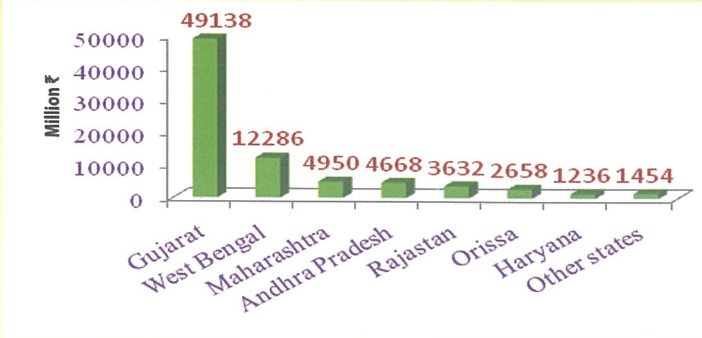

Fig. 3. State-wise annual monetary losses due to salinity

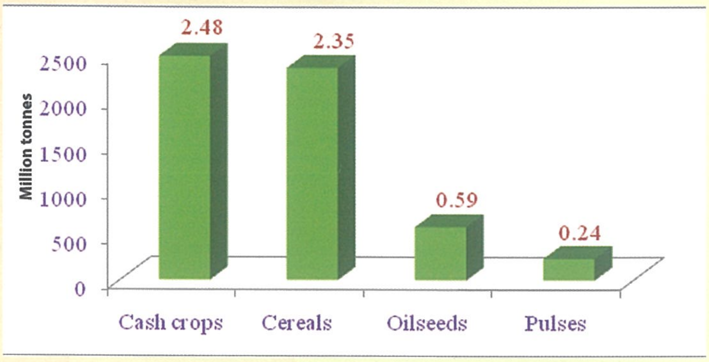

Fig. 4. Crop category-wise annual production losses due to salinity

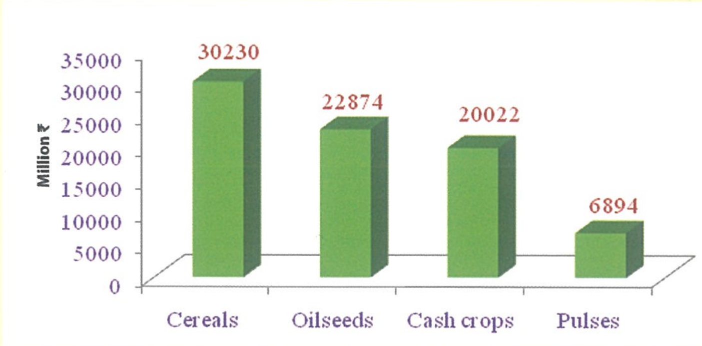

Fig. 5. Crop category-wise annual monetary losses due to salinity

Among cash crops, cotton accounted the monetary loss of ₹ 10,000 million (13%) followed by sugarcane (₹ 5,000 million) and potato (₹ 5,000 million). The share of pulses in the total monetary losses is ₹ 7,000 million (9%), out of which other pulses contributed ₹3,000 million (3.66%) followed by Bengal gram (₹ 1,860 million), green gram (₹ 1,490 million), pigeon pea (₹ 310 million) and black gram (₹ 280 million). Among the crops, groundnut, rice and cotton suffered highest monetary losses due to salinity. It is assessed that India can add 5.66 M t of farm production annually upon reclamation of entire area affected by soil salinity.

Subsurface drainage technology

The waterlogged saline soils can be reclaimed by subsurface drainage (SSD) technology developed and standardized by ICAR-CSSRI, Karnal in collaboration with The Netherlands through field experimentation under different agro-climatic conditions. The system consists of a network of perforated corrugated/smooth PVC pipes (laterals and collectors as shown in left portion of Fig. 6. These pipes are covered with gravel/synthetic filter to prevent clogging and are installed manually or by laser controlled trencher machines mechanically at a desired design spacing and depth below soil surface. Such a drainage network helps in maintaining water table below the root zone depth and drains excess water and salts out of the affected area through gravity or pumped outlet. In case of pumped outlet, provision of a sump (as in right portion of Fig. 6) to collect and to pump drainage water is required. Thus, system works naturally under gravity outlet while requires additional cost of pumping under pumped outlet. The depth and spacing of the drainage system are decided on the basis of drainage coefficient (depth of water in mm that is to be drained from drainage area per day) worked out considering rainfall, irrigation, crop rotation, soil texture, hydro-geology, soil salinity and outfall conditions. Based upon overall experience of CSSRI, design parameters of subsurface drainage have been standardized for different regions (Table 2). In addition to above, the recommended values of minimum slope of drain pipes are 0.10 to 0.05 % for drain pipes of 100 to 150 mm diameter.

Table 2. Design parameters of SSD for different regions of India

Drainage coefficient (mm/d)			Drainage depth (Dd)		Drain spacing (Ds)	
Climate	Range	Optimal	Outlet type	Dd (m)	Soil texture	Ds (m)
Arid	1-2	1	Gravity	0.9-1.2	Light	100-150
Semi arid	1-3	2	Pumped	1.2-1.8	Medium	50-100
Sub Humid	2-5	3			Heavy	30-50

In large scale drainage projects undertaken under Governmental schemes in alluvial soils of Haryana, the recommended drain parameters are 66 m (along field boundary line) drain spacing and 1.5 m average lateral depth. In case of heavy texture soils/Vertisols of

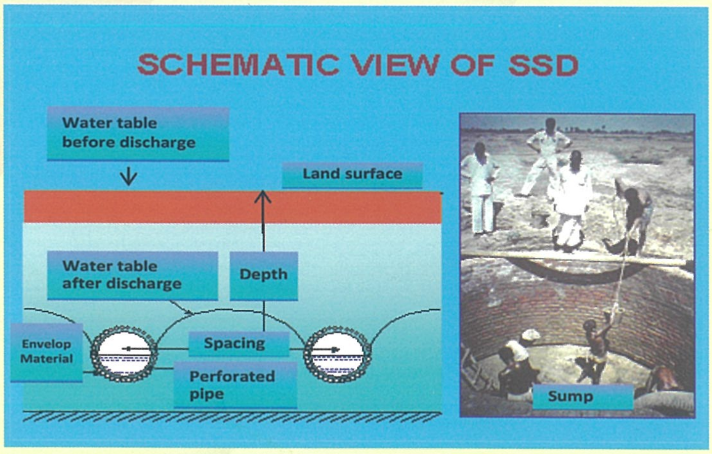

Fig. 6. Schematic diagram of subsurface drainage system

peninsular India, 30 m drain spacing and 1.2 m average depth are common.

In waterlogged saline soils reclaimed through subsurface drainage in different states, the crop yields increase significantly, more than 50% for paddy and more than 100% in wheat and cotton. Results also suggest 40% improvement in cropping intensity leading to 2- 3 fold increase in farmers' income.

Investment cost

The cost of subsurface drainage varies from one place to another depending upon depth and spacing combination which further depends upon soil type and topography. The estimated cost at 2015 price level is ₹ 65,000 per ha under Govt. funded schemes for alluvial soils of Haryana and ₹ 1,25,000 per ha for heavy textured soils (Vertisols) of Maharashtra and Karnataka. While the material cost in Haryana accounts for nearly 60-65% of total cost, the labour and machinery cost accounts for 20-25% of the total cost. The land development cost (10-20%) depends on the extent of salinity and waterlogging problem in the area. Severely affected areas require higher land development cost mainly due to clearing of unwanted *Prosopis juliflora* and other bushes and land levelling operations. The miscellaneous expenses in large scale drainage project include expenses on account of survey and drainage investigation, preparation of detailed project report, construction of approach road and main drain, stakeholders' training, dewatering and unforeseen activities.

Benefits of Sub-surface Drainage Technology

Haryana: The subsurface drainage technology is being implemented by Haryana Operational Pilot Project (HOPP), Department of Agriculture, Haryana in technical collaboration with CSSRI. Till May 2016, subsurface drainage has been provided in about 10,000 ha waterlogged saline areas in Rohtak, Jhajjar, Sonipat, Sirsa, Bhiwani, Kaithal, Jind, Fatehabad and Palwal districts of Haryana.

Impact analysis of large scale project at Gohana in Sonepat district by ICAR-CSSRI revealed that water table remained at 1.07 m in drained area compared to 0.63 m in undrained area. There was significant reduction in root zone soil salinity during rainy season which helped to maintain favourable salt balance of drained fields. The salinity of drainage effluent improved and it ranged from 1.23 to 3.03 dS m^{-1} in different locations. Such waters can safely be recycled for irrigation during the *rabi* season. Reduction in soil salinity resulted in improvements in crop productivity, in wheat around 41% and 64% in pearl millet. The average wheat yield was 3.6 and 2.4 t ha^{-1} in drained and un-drained areas, respectively, indicating a significant increase in wheat yield due to the sub-surface drainage system. The real impact of subsurface drainage was not limited to an improvement of the *kharif* season crop but it helped in early sowing of *rabi* crop by improving conditions for movement of machineries.

Economic analysis of SSD implemented in different states indicated that the benefit cost ratios varied from 1.5 to 3.2. While internal rate of return varied between 17% to 58% with payback period from 3 to 5 years.

Maharashtra and Karnataka: Two pilot subsurface drainage projects were completed in 1692 ha heavy (vertisols) black soils in lift irrigated schemes of Krishna river basin in Sangli district of Maharashtra, with funding under MoRD, Government of India. Both projects were executed through Public-Private Partnership (PPP) mode. About 1000 ha area in Belgaum district of Karnataka has also been provided with SSD in similar PPP mode. The subsurface drains were installed at 30 m spacing and 1.0-1.5 m depth for laterals and 2.0 m for collector. The outlet for disposal of drain water is mostly by gravity into surface drains requiring no pumping cost. The investment cost of SSD in Maharashtra and Karnataka is ₹ 1,25,000 per ha shared by the Central government, State government and the beneficiary in the ratio of 60:20:20, while 100% cost for construction or maintenance of surface main drain is borne by state government. The performance of the system has been promising as sugarcane and turmeric have been tried by farmers along with other crops in drainage areas.

Observing the quick returns of subsurface drainage in terms of water table control, reduction of soil salinity and enhancement of income due to increase in crop yields, a large number of farmers are coming forward to adopt SSD with own investment. During the past 5 years, subsurface drainage activities have picked up in heavy black cotton soils of Maharashtra and Karnataka in a very impressive way. Once installed, the operating cost of drainage system is virtually nil since drainage water is discharged into open surface drain under gravity.

These and other similar case studies conclusively establish that a substantial increase in farm income can be achieved by subsurface drainage through: (i) increase in cropping intensity; (ii) shift in cropping pattern towards more remunerative crops; (iii) increase in crop yields; (iv) increase in gainful employment; (v) conversion of moderate and marginal lands to productive agricultural use and finally (vi) increase in input use efficiency. The well installed and effectively managed subsurface drainage systems indirectly contribute to national development.

Way Forward

Subsurface drainage is a technically and financially viable technology for the amelioration of waterlogged saline soils in the irrigation commands of India. Nonetheless, Socio-economic issues, farmers' participation, post-reclamation pumping, organizational set up in states and training of technical personnel is vital for long-term success. Considering the extent of waterlogged saline soils, procurement of new machinery, enhanced Government funding through CADA and RKVY and outsourcing of subsurface drainage projects in PPP mode can speed up large scale implementation of reclamation projects.

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