

RECENT ADVANCES IN MANAGEMENT OF SALINE WATERLOGGED SOILS AND POOR QUALITY WATER IN INDIA

PROGRÈS RÉCENTS RÉALISÉS DANS LA GESTION DES SOLS DETREMPÉS D'EAU SALÉE ET DE L'EAU DE MAUVAISE QUALITÉ EN INDE

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ABSTRACT

As per recent estimates nearly 953 million ha area is affected by salinity and sodicity in the world. Australia followed by north and central Asia and South America have the maximum problem of high salt concentration in the root zone soil. The climate change triggered frequency of weather related events like floods, droughts, frost, cold and heat waves has considerably increased during last two decades in India. Continuation of such trends associated with rise in temperature is expected to melt ice, glaciers, re-distribute water flow in rivers, raise sea levels, sub-merge coastal habitats, islands, generate tsunamis and dislocate human and livestock settlements. About 6.73 million ha otherwise productive area is constituted by salty lands in India. Gujarat state followed by UP has maximum area affected by salinity and sodicity. It has been further projected that about 12 million ha area will be affected by 2030. Similarly, about 25% of the ground water resources in India are saline and/or brackish. Continuous use of such water for irrigation is bound to increase soil salinity/sodicity. States like Rajasthan and Haryana have 84% and 62%, respectively ground water as saline/sodic. Introduction of irrigation in canal command areas coupled with over use of water has resulted in rise in ground water. In some of the canal commands water table is rising @ 0.3 to 1.2 meter/annum. Nearly 3.55 million ha is already water logged and gone out of cultivation. Losses in productivity due to water logging are reported 42% in paddy, 38% in wheat, 77% in cotton and 61% in sugarcane compared to productivity of these crops in normal soils. After the establishment of Central Soil Salinity Research Institute in 1969 at Karnal, several site specific technologies have been developed for reclamation and management of saline water logged lands, alkali soils and for efficient use of poor quality water. A gist of the relevant technological options is discussed in this paper. The Topics covered included : (i) extent, distribution and nature of salt-affected soils and poor quality water in different regions of India; (ii) surface, sub-surface, vertical drainage and bio-drainage technologies for management of water logged areas; (iii) salt tolerant crops, varieties and halophytes; (iv) Dourov technology for skimming floating good quality rainwater over saline water in coastal areas; (v) consumptive and mixed use of poor quality water with good quality water and (vi) future research and development need for management of salt-affected soils and poor quality water.

Keywords: Water Logging, Salinity, Sub-surface drainage, Biodrainage, Salt tolerant crops, Poor quality water.

RESUME

D'après des estimations récentes, près de 953 millions d'hectares de terre est affectée par la salinité et la sodicité dans le monde. L'Australie, suivie de l'Asie du Nord et centrale, ainsi que l'Amérique du Sud sont confrontés au plus grand problème de concentration élevée de sel dans le sol de la zone racinaire. Au cours des deux dernières décennies, l'Inde a connu une augmentation considérable de la fréquence des événements météorologiques extrêmes — tels que les inondations, les sécheresses, les gelées ainsi que les vagues de froid et de chaleur — induits par le changement climatique. La poursuite de ces tendances associées à l'augmentation de la température devrait faire fondre la glace, les glaciers, redistribuer le débit fluviaux, provoquer une élévation du niveau de la mer, immerger les habitats côtiers

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et les îles dans la mer, générer des tsunamis et déstabiliser les établissements humains et d'élevage. Environ 6,73 millions d'hectares de terres par ailleurs productives sont transformées dans les terres salées en Inde. L'État du Gujarat, suivi par l'UP, a une superficie maximale affectée par la salinité et la sodicité. On prévoit en outre qu'environ 12 millions d'hectares de terre seront touchés d'ici 2030. De même, environ 25% des ressources en eau souterraine en Inde sont salines et/ou saumâtres. L'utilisation continue de cette eau pour l'irrigation donne lieu à l'augmentation de la salinité/sodicité du sol. Des États tels que le Rajasthan et l'Haryana possèdent 84% et 62% respectivement d'eau souterraine sous forme saline/sodique. L'introduction de l'irrigation dans les zones desservies par des canaux, associée à une utilisation excessive de l'eau, a entraîné une augmentation des eaux souterraines. Dans certains de ces zones, la surface de la nappe phréatique augmente de 0,3 à 1,2 mètre par an. Près de 3,55 millions d'hectares de terre sont déjà détrempés et ne sont plus cultivés. Les pertes de productivité dues à l'engorgement sont signalées à 42% pour le paddy, 38% pour le blé, 77% pour le coton et 61 % pour la canne à sucre par rapport à la productivité de ces cultures dans des sols normaux. Après la création de l'Institut central de recherche sur la salinité des sols en 1969 à Karnal, plusieurs technologies spécifiques au site ont été développées pour la remise en état et la gestion des **terres** détrempées salées, les sols alcalins et pour une utilisation efficace de l'eau de mauvaise qualité. Les principales options technologiques pertinentes sont examinées dans le présent document. Les thèmes abordés étaient les suivants : i) l'étendue, la distribution et la nature des sols salins et de l'eau de mauvaise qualité dans différentes régions de l'Inde; ii) les technologies de drainage de surface, souterrain, vertical et de biodrainage pour la gestion des zones détrempées; iii) les cultures et les variétés tolérantes au sel ainsi que les halophytes; (iv) la technologie «Dourov» permettant de prélever, par écrémage, les eaux de pluie de bonne qualité flottant au-dessus des eaux salines dans les zones côtières ; (v) la consommation et l'utilisation mixte de l'eau de mauvaise qualité avec l'eau de bonne qualité et (vi) les besoins futurs en matière de recherche et de développement pour la gestion des sols affectés par la salinité et des eaux de mauvaise qualité.

Mots-clés : Engorgement; Salinité; Drainage souterrain; Biodrainage; Cultures tolérantes au sel; Eau de mauvaise qualité.

Introduction

Productivity of 6.73 million ha otherwise productive land is limited by the presence of high salt concentration in the root zone soil (Singh, 2008). Similarly, about 25% of ground water in India is also of poor quality. Irrigation using such water is bound to increase salinity problem. Further, introduction of canal irrigation in arid and semi-arid regions without provision of adequate drainage causes rise in water-table leading to waterlogging and secondary salinisation. Presently, about one-third of the world's irrigated area faces the threat of waterlogging. The problems of waterlogging and salinity can be effectively tackled by conventional surface and sub-surface drainage systems, provided these are properly designed, installed, maintained and operated. However, these are more expensive and sometimes cause environmental problems.

The alternative approaches must be effective, affordable, socially acceptable, environment friendly, sustainable and upgrade precious natural resources. Systematic research in India and abroad for last about five decades developed location specific technologies for the reclamation and management of sodic soils, saline soils and also for the judicious use of poor quality water. A brief account of these technologies including good management practices is discussed in this paper.

Extent, Nature and Distribution of Salt Affected Soils

As per recent estimates, nearly 953 million ha area is affected by salinity and sodicity in the world (Table 1). Australia followed by north and central Asia and South America have the largest problem of high salt concentration in the root zone soil. With the introduction of irrigation in the arid and semi-arid areas of the world, the problem of salinity is bound to increase. Globally, the salt-affected soils are broadly placed into two categories solanchaks (saline) and solonetz (sodic).

The solanchaks are predominated by the presence of soluble salts like chlorides, calcium, magnesium and sulphate salts and generally have good water transmission characteristics. On the other hand, the solonetz are dominated by the presence of sodium carbonate and sodium bicarbonate salts. Those soils have very low in filtration rate.

Table 1: Distribution of salt affected soils in the world (million ha)

Region	Solonchaks / Saline	Solonetz / Sodic	Total
North America	6	10	16
Mexico and Central America	2	-	2
South America	69	60	129
Africa	54	27	81
South and West Asia	83	2	85
South and East Asia	20	-	20
North and Central Asia	92	120	212
Australia	17	340	357
Europe	-	51	51
Total	343	610	953

Statewise area affected by salinity and sodicity in India is given in Table 2. As per reconciled data, about 6.73 million ha otherwise productive area is designated as salty lands. Gujarat state followed by UP has largest area affected by salinity and sodicity. It has been further projected that 11.7 million ha area will be affected by 2030.

Table 2: Extent of salt affected soils in India (ha)

State	Saline	Sodic	Total
Andhra Pradesh	77598	196609	274207
Andaman & Nicobar Island	77000	0	77000
Bihar	47301	105852	153153
Gujarat	1680570	541430	2222000
Haryana	49157	183399	232556
Karnataka	1893	148136	150029
Kerala	20000	0	20000
Madhya Pradesh	0	139720	139720
Maharashtra	184089	422670	606759
Orissa	147138	0	147138
Punjab	0	151717	151717
Rajasthan	195571	179371	374942
Tamil Nadu	13231	354784	368015
Uttar Pradesh	21989	1346971	1368960
West Bengal	441272	0	441272
Total	2956809	3770659	6727468

Projections by 2030: 11.7 million ha Source: CSSRI, Karnal

Salt-affected soils in India are broadly classified into alkali (sodic) and saline soil. Alkali or sodic soils are characterized by high pH₂ more than 8.5, high exchangeable sodium (ESP) of more than 15 and electrical conductivity (EC) less than 4 dSm⁻¹. In some cases the ESP is much higher given the name a sodic soils. Because of high amount of sodium (Na), these soils are deflocculated having low water infiltration rate.

On the other hand, saline soils are characterized by low pH₂ less than 8.5, low ESP less than 15 and high EC of more than 4 dSm⁻¹. The predominant salts include chlorides and sulphates of Ca, Mg and Na. These soils have high water infiltration capacity and can be reclaimed through leaching

Nearly 25% of the ground water resources in India are saline and / or brackish. Continuous use of such water for irrigation is bound to increase soil salinity / sodicity. States like Rajasthan and Haryana have 84% and 62%, respectively ground water as saline / sodic. Percentage use of poor quality waters in selected states is given in Table 3.

Table 3: Percentage use of poor quality waters in different states

State	Percentage (estimated values)
Andhra Pradesh	32
Gujarat	30
Haryana	62
Karnataka	38
Madhya Pradesh	25
Rajasthan	84
Uttar Pradesh	47

Source: CSSRI, Karnal

Introduction of irrigation in canal command areas coupled with overuse of water has resulted in rise in ground water. In some of the canal commands, water table is rising at 0.3 to 1.2 meter / annum (Table 4). Nearly 3.55 million ha is already water logged and gone out of cultivation. Statewise extent of waterlogged area is reported in Table 5.

Table 4: Rising trend of water table in irrigation commands

Irrigation command	Rise of water table (meter / annum)
IGNP, Rajasthan	0.29 – 0.88
Western Yamuna and Bhakra canal	0.30 – 1.00
Sharda Sahayak, U.P	0.68
Nagarjuna Sagar, A.P	0.32
Malprabha canal command, Karnataka	0.60 – 1.20

Table 5: Extent of waterlogged areas in India

State	Waterlogged area (m ha)
Andhra Pradesh	0.43
Bihar	0.35
Gujarat	0.17
Haryana	0.23
Karnataka	0.05
Kerala	0.08
Madhya Pradesh	0.06
Maharashtra	0.02
Orissa	0.18
Punjab	0.30
Rajasthan	0.18
Tamil Nadu & Pondicherry	0.61
Uttar Pradesh	0.59
West Bengal	0.29
Total	3.55

Source: Ministry of Agriculture

Impact of Water Logging and Salinity on Agriculture

Losses in productivity due to water logging are reported 42% in paddy, 38% in wheat, 77% in cotton and 61% in sugarcane compared to productivity of these crops in normal soils (Table 6)

Table 6: Losses in productivity due to water logging and soli salinity

Crop	Normal lands	Salt affected lands	Waterlogged lands
Paddy	39.9	21.8 (45)	23.0 (42)
Wheat	26.0	15.8 (40)	18.6 (38)
Cotton	16.3	6.1 (63)	3.7 (77)
Sugarcane	636.8	330.2 (48)	247.5 (61)

Source: CSSRI, Karnal

Reclamation and Management Strategies

After the establishment of Central Soil Salinity Research Institute in 1969 at Karnal, several site specific technologies have been developed for reclamation and management of saline and alkali soils. A gist of the relevant technological options is discussed as under. Alkali or sodic soils can be reclaimed through the application of amendments like gypsum and pyrites. The dose of amendments depends upon the gypsum requirements of the soil which varies with type of soil, crops to be grown and level of management practices. About two million ha area is reclaimed which is contributing more than 20 million ha additional food grains.

Sub-surface drainage technology has been developed to reclaim waterlogged saline soils (Fig 1). This technology involves laying perforated drains at a depth of 1.2 to 1.6 meter below ground level to drain excess water from the field. The drainage material, depth and diameter varies from location to location depending upon type of soil, severity of the problem and crops to be grown. These drains are then joined to a sump for collection of drainage water. The drained water can be recycled in situ, if salinity is low or alternately connected to major drainage system. High cost of installation, maintenance and disposal of large volume drainage effluent are some limitations for large scale adoption. Statewise drained area covered is given in Table 7. Similarly, change in cropping intensity after installation of the drainage system is reported in Table 8.



(Figure 1)

Table 7: State wise drainage area covered

State	Irrigation command	Area covered (ha)
Rajasthan	Chambal	15,700
	Indira Gandhi Nahar Pariyojan	500
Haryana	Eastern Jamuna Canal	1450+3000
	Bhakhra Canal	1300+1000
Punjab	South West Punjab	30+2000
Karnataka	Upper Krishan	30
	Tungabhadra	200
	Malparhba Ghatparbha	20
Andhra Pradesh	Nagarjuna Sagar	50
	Krishan Western Delta	50
Madhya Pradesh	Unspecified	50
Maharashtra	Uncommanded Neera Canal Command / others	1000+1000
Gujarat	Mahi – Kadana	150
	Ukai – Kakrapar	80
Kerala	Acid Sulphate Soils	30
Assam	Tea Gardens	15

Source: CSSRI, Karnal

Table 8: Change in cropping intensity

Place	Before drainage	After drainage	Increase (%)
Sampla	0	200	-
Ismaila	73	148	103
Gohana	117	175	50
Konanaki	70	90	29
Uppugunduru	130	165	27
Islampur (Karnataka)			
ORP	0	200	-
Phase II	88	156	77

Source: CSSRI, Karnal

Several salt tolerant varieties of rice, wheat and mustard have been developed which can be grown either without or with half the recommended dose of amendments. The promising varieties are listed below:

- Rice: CSR 10, CSR 13, CSR 23, CSR 27, CSR 30, CSR 36, CSR 101, CSR 105
- Wheat: KRL 1-4, KRL 19, KRL 210 and KRL 213
- Mustard: CS 52, CS 54, CS 56, CS 62

Besides these, salt tolerant trees, grasses, bushes, biofuel crops have been identified and agro-techniques for their successful cultivation in salty lands standardized. Several multipurpose tree based silvi-agri and agroforestry models have been developed for fuelwood and forage production and bio-amelioration of both sodic and saline soils. An augerhole technique for establishing tree plantations in soils of pH₂ >10.0 was developed. Several village community lands affected by salinity / sodicity have been planted with trees like *Prosopis juliflora*, *Acacia nilotica*, *Eucalyptus tereticornis*, *Casuarina equisetifolia* and *Tamarix articulata*. The augerhole technique was further improved as pit-augerhole technique which made it possible to grow even fruit trees such as amla, guava, jamun, karaunda, Ber and imly in salty lands. Trees and grasses once established in salt lands help reclamation of such soils by root activity and addition of leaf litter.

Association of salt-tolerant grasses like *leptochloa fusca* with trees further hastens the reclamation process. The short, medium and long term effects of trees on soil properties in general and carbon sequestration in particular is reported in Table 9 and 10. The perusal of the data clearly indicates that significant amount of carbon is sequestered in the soil. The extent of carbon build-up depends upon the nature of tree species, planting density, age of plantation and the management practices.

Table 9: Reclaiming effects of *Prosopis juliflora* plantations on village community lands

Village	Depth (cm)	Soil properties			
		pH		Organic carbon (%)	
		Initial	After 8 years	Initial	After 8 years
Shera	0-15	10.0	8.8	0.13	0.48
	15-30	10.1	9.6	0.06	0.21
Sutana	0-15	10.2	8.5	0.20	0.40
	15-30	10.6	9.4	0.07	0.09
Nain	0-15	9.7	8.6	0.08	0.45
	15-30	10.2	9.2	0.10	0.12
Bhalsi	0-15	10.0	8.8	0.22	0.65
	15-30	10.5	10.1	0.08	0.12

Source: Singh et al 199

Table 10: Ameliorating effects of mesquite and other tree plantations on an alkali soil

Species	Original		After 20 years	
	pH ₂	Organic carbon (%)	pH ₂	Organic carbon (%)
Eucalyptus tereticornis	10.3	0.12	9.18	0.33
Acacia nilotica	10.3	0.12	9.03	0.55
Albizia lebbek	10.3	0.12	8.67	0.47
Terminalia arjuna	10.3	0.12	8.15	0.47
Prosopis juliflora	10.3	0.12	8.03	0.58

Source: Singh et al, 1998

Role of trees having high transpiration rates has been exploited to lower the water table in areas where ground water is showing rising trends. This process is known as bio-drainage Singh and Lal, 2018. Bio-drainage is defined as the process of removing the excess soil water through transpiration using bio-energy of the plant and radiation energy of the Sun. It is an option to prevent the development of waterlogged and saline soils especially in land locked areas where there is no possibility of disposing saline drainage effluent. Also there are large areas which get water stagnation due to seepage from higher elevation, surface disposal of urban and industrial effluents and floods during rains, where due to their topographical locations, conventional system of de-watering through mechanical pumping and surface drainage is not possible. Promising tree species for bio-drainage use include: Eucalyptus, jamun, shisham, bamboo, poplar etc.

Sub-surface drainage for reclamation of saline waterlogged soils is a proven technology. However, this technology can be effectively implemented when large chunk of saline waterlogged land is available in a continuous stretch, land topography is favourable and there exists a natural drainage system to carry large volume of saline drained water out of the area. Areas where salt lands do exist in patches and land topography does not support sub-surface drainage on account of operational and economic considerations, an alternate option of integrated farming system with major emphasis on saline aquaculture is an option of promise. The workers at the Central Soil Salinity Research Institute, Karnal have developed location specific integrated farming systems for salty lands in Haryana, Gujarat, UP and West Bengal situations (Singh, 2025). These interventions need up-scaling.

Future Research, Development and Policy Need for Management of Salt-affected soils and Poor Quality water

- Location specific proven technologies are now available for the reclamation and management of almost all kinds of salt-affected soils. The states need to reclaim those location specific areas using funds available in schemes like RKVY etc.
- There is strong need to develop and propagate salt tolerant crops and varieties using biotechnological approaches. There is need to search for genes from highly salt tolerant plants like mangroves, *Prosopis* and *Salicornia* etc. and their incorporation in cultivation crops.
- As an alternate to sub-surface drainage for reclamation of water logged saline lands locations specific saline aquaculture based integrated farming systems need to be developed and promoted.
- Prevention is better than cure. In all canal command areas where flood irrigation is practiced and areas showing rising ground water trend, high transpiration trees such as *Eucalyptus* should be planted along with crops in a unified agroforestry system. Belts of high transpiration trees need to be raised along canals to tap seepage in-situ and thus preventing rise in water table and salinity development in the adjoining areas.

- Gypsum is the most commonly used amendment for reclamation of alkali or sodic soils. Availability of gypsum and its cost may be an issue in the near future. There is an urgent need to find alternate cheap amendments for future use in alkali or sodic soil reclamation.
- Climate change triggered rise in sea water level has been predicted. Intrusion of sea water in good lands may result in salinity build up in coastal areas. Focus on preventive measures to halt salinization in coastal areas is the need of the hour.
- Reuse of water including poor quality salty waters for agriculture need to be high priority research in salinity management.
- There is a need for value addition of products obtained from highly salt-tolerant plants naturally growing in these areas such as genus *Prosopis*, *Slavadora*, *Atirplex* etc.
- More pumping of ground water in good quality ground water regions to irrigate water guzzling crops like rice and sugarcane run the risk of saline water intrusion from adjoining areas and thus deterioration in ground water quality. This calls for diversification into low water requiring crops and cropping systems to halt salinity problem in normal crop growing areas in the near future.

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