Meeting Challenge of the Water Shortage: Rainwater Conservation in Land Reclamation Programs

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Abstract: The additional water required for the reclamation of agricultural lands might not be available in adequate quantities and at an appropriate time. Since the demand for the limited water in arid and semi-arid regions is increasing, it calls for in-situ conservation of rainwater. A rainwater conservation technology is proposed that form a part of the alkali land reclamation programs. This technology if adopted, could conserve more than 80% of the rainwater in the area where it falls. On-farm development activities and leaching with saline water that occur naturally are proposed for in-situ conservation of rainfall to leach saline soils. The rainwater utilization for leaching in this manner could almost be doubled. Use of saline water for leaching is also highlighted. With this approach, a 15%—40% saving in the fresh water requirement could be attained. A pitcher irrigation technique for irrigation with saline water is also described. It is shown that highly saline water even up to 15 dS/m EC could be used to grow salt sensitive vegetable crops. Some of these technologies could be extended to normal lands to augment the scarce natural resource, minimize drainage and avoid flooding at the tail ends.
Keywords: Rainwater conservation, surface drainage, leaching, pitcher irrigation, saline water

1 Introduction

In most regions of India, the nature of agricultural production is governed by the availability of water at one time or the other. As such, irrigation water is being diverted through projects of gigantic magnitude. In many case it entails inter-basin transfer of water. Since most of these projects are being implemented with inadequate provisions of drainage, rise in the water table has been an inevitable consequence of such projects. With the expansion of soil salinity as a result of secondary soil salinization, realization to prevent the spread of waterlogging and soil salinity has emerged. Land reclamation programs are also being planned and implemented to revert the fertile lands that have gone out of production. In such land reclamation programs, the importance of water is more than before since water is the carrier of salts as well as essential input to transport the salts out of the profile. Thus, on the one hand it creates the problem while on the other it acts as a solution provider. The only distinction between the creation and solution provider is whether we manage or mismanage the water.

Contrary to this scenario, the burgeoning population, improvement in the standard of life, industrial growth, and increasing requirements for ecological and recreational needs, all are exerting a lot of pressure on the precious water resource. It is anticipated that by 2,025, the water requirement would increase by 40%. With intense competition ahead between the various sectors, it would be the agricultural sector that would be used as a sacrificial goat and forced to release water to meet the increasing demand of the other sectors. As a result, share of agriculture sector would decline from the present 83% to about 74%. It is in this context, unconventional sources of water such as saline ground water, reuse of domestic and industrial wastewater and others are being explored for use in agriculture.

While lot of emphasis is being placed on the use of poor quality waters, it is a matter of great concern that, the most precious good quality rain water is being wasted and allowed to run-off to the sea in the name of drainage. In the monsoon climatic conditions, where 80% of the rain is likely to occur in about 100 hours in a year, the common approach is to lead the excess water to natural drainage system to avoid waterlogging/flooding. As such, rainwater utilization efficiency in many areas is as low as 20%—30%. It may be interesting to note that if this efficiency is increased say by 10%, many problems related to water shortage can be overcome. The objective of the present paper is to highlight in-situ rainwater conservation technologies in land reclamation programs besides dealing with an irrigation technique to conserve water and use of saline water in crop production. It is highlighted that some of these technologies could be extended to normal lands to augment the scarce natural resource to minimize drainage and to avoid flooding at the tail ends.

2 Extent of the problems

Expansion of irrigation and research and development in agriculture together brought out revolutionary changes in agricultural production in India. As such we could ensure the food security of India. It is counted as one of the major success stories of the post-Independent India. This success, however, is not unblemished. The self-sufficiency in food grains production could be achieved at the expense of natural resources of India. As such, land degradation and scarcity of the water resources threatened the sustainability of Indian agriculture. It is estimated that about 8.5 million ha of agricultural land is lying barren as a result of chemical degradation. Roughly, the salt affected soils could be categorized in 3 groups namely alkali lands (about 2.0 million ha), inland saline lands (about 3.5 million ha) and coastal saline lands (3.0 million ha). Similarly, large areas are threatened with depleting ground water. As many as 137 districts in India experienced falling water table. Here water table went down more than 4 m during 1980—1998 (Table 1). Many more districts and blocks are now experiencing the fall in the ground water table. It seems that this paradoxical situation of rising and dropping water table would continue to stare the agricultural sector in the coming few decades.

Table 1 Parts of states having decline of water table more than 4 m during 1980—1998

State	No. of Districts	State	No. of Districts
Haryana	12	Madhya Pradesh	22
Punjab	9	Karnataka	11
Rajasthan	26	Tamil Nadu	10
Gujarat	7	Bihar	2
Uttar Pradesh	24	Maharashtra	1
West Bengal	1	Andhra Pradesh	6
Assam	4	Orissa	2

(Sharma and Kaushik, 1998)

3 Rain water conservation in alkali lands

Central Soil Salinity Research Institute, Karnal has come out with a package that needs to be implemented to reclaim alkali lands. As such, more than 1 million ha of alkali lands have been reclaimed in 3 states of India over the last 3 decades (Table 2). The technology package consists of the following steps:

- Land leveling and construction of field dykes (*bunds)*
- Adequate drainage provision for removal of excess water
- Assured source of good quality irrigation water
- Application of amendments
- Leaching
- Selection of crops and cropping sequences
- Nutrient management
- Agronomic practices for growing rice and wheat.

One of the points in the package is adequate drainage that calls for improved surface and subsurface drainage. To achieve efficient drainage and to conserve rainfall for its possible reuse during dry spells, a three-tier rainwater management technology was proposed and tested. Briefly, the 3 tiers of the system are:

- Rainwater is allowed to accumulate and remain on the cropland till such time and extent that it will not adversely affect the crop.

- Excess water from the fields is led to the dugout ponds or natural depressions of sufficient capacity. The stored water is utilized subsequently during dry spells or for irrigating winter season crops.
- Rainwater in excess of these two compartments of storage is led out of the area to the natural drainage system through tertiary and main drains.

Table 2 Reclamation of alkali lands in 3 states of India

State	Extent of Area (m/ha)		Land reclaimed (m/ha)
	1971	1995—2000	
Punjab	0.700	0.153	0.547
Haryana	0.530	0.164	0.366
Uttar Pradesh	1.200	1.060	0.14
Total	2.430	1.3 17	1.113

The first compartment of the system is a crop based component and was therefore, tested for a number of years during which rainfall varied from below average to above average. It was observed that rice yield is affected both by the depth of water stored as well as the time for which such depths of water are stored in the rice fields. However, adverse effects were only experienced once in the five years of testing when the rainfall and the storms exceeded five years return period values. The analysis revealed that even during this year, 20%—25% of the rain water drainage gave yield comparable to the drained plots (Gupta and Pandey, 1979).

The rainwater storage, on the other hand, not only reduced the irrigation water requirement but also increased the ground water recharge (Table 3). The net benefit to ground water ranged from 8 cm—40 cm depending upon the total rainfall in the season. Therefore, this should help to stabilize the falling water table in areas with alkali problems since rice based cropping systems are recommended during reclamation of these lands. In this set-up, rice fields serve as ground water recharge basins (Gupta, 1983) and more than 80% of the rainfall can be conserved within the areas where it falls in the semi- arid regions with an average annual rainfall of 700 mm—800 mm. This strategy has since been tested at many places in the country and the results are in tune with the findings reported herein.

Table 3 Irrigation water requirement and benefit to ground water recharge due to rainwater storage in rice fields

Irrigation and rainwater used (cm)		Reduction in groundwater load (cm)	Drainage need for optimum crop yield (cm)	Extra recharge (cm)	Net benefit to groundwater (cm)
Complete storage (Un-drained)	Removal of rainwater above 5 cm, 24 hr after the storm (Drained)				
35 (37.1)	40.0 (29.1)	5.0	0	3.2	8.3
10.0 (60.5)	40.0 (20.8)	30.0	0	9.7	39.7
7.2 (64.0)	49.7 (11.4)	42.5	16.0	10.1	36.6
33.0 (47.9)	46.1 (27.9)	13.1	0	2.8	18.3
27.7 (39.8)	43.2 (20.5)	15.5	0	2.8	18.3

In situ conservation of rainfall for saline lands

The package of practices for reclamation of saline lands consists of the following steps:

- Land grading, construction of field dykes and surface drainage
- Horizontal Subsurface Drainage to Control Water Table
- Leaching

- Selection of Crops and Cropping Sequence
- Improved Cultural Practices

In this package, leaching of salts with application of excess leaching water is essential. In arid and semi-arid regions, where surface irrigation systems have been implemented through inter-basin transfer of irrigation water, water is not only inadequate for crop production but its reliability is also questionable. To supply additional water for leaching seems to be quite a difficult proposition. Therefore, a two-way approach has been proposed.

- On-farm development activities for in-situ conservation of rainfall
- Conjunctive use of saline and fresh water for leaching

Rainwater is the best quality water available for leaching of waterlogged saline soils or soils irrigated with saline water. In the Indian context ample evidences are available that a substantial fraction of the salts is leached down during the monsoon season. Some of the factors that influence the fraction of the salts leached are:

- intensity and duration of the rainfall
- duration of dry spells between rain events
- land levelling and construction of field dykes
- condition of the top layer of the soil
- initial salinity and its distribution in the profile and
- initial moisture content in the profile at the time of rain event

Although two first mentioned factors can not be controlled, yet to make effective use of the rainfall, other factors could be altered to improve rainfall utilization for leaching. Based upon field observations, it has been seen that under natural conditions, only 10%—30 % of the rainfall is effectively used for leaching (Gupta, 1985). In cultivated fields where some kind of dykes are made and to some extent levelling is also undertaken, the rainwater utilization improves to 55%—70%. Based on these observations, an on - farm management package consisting of construction of field dykes, land levelling and tillage of the land surface has been developed. The increased rainwater utilization for leaching with various components of the package has been reported in Table 4. It has also been observed in several studies that initial moisture content in the soil profile at the time of occurrence of the rainfall helps greater fraction of the rainwater to percolate below a given depth. As such it would effectively leach down more salts than in a dry profile. It is, therefore, suggested that further improvement in the leaching through rainfall could be achieved provided partial leaching is accomplished through saline water before the onset of the monsoon season. In our opinion, more than 80 % of the salts can be leached down with appropriate levelling, construction of field dykes and tillage (Gupta, 1992). This percentage can further be increased by implementing other steps in the package as well as by ensuring a good quality work.

Table 4 Rainwater utilization efficiency at various stations in Haryana and Rajasthan

State / Station	Field description	Soil type	Rainwater utilization efficiency (fraction)
Western Rajasthan			
Dantiwada	Bunded levelled	Sandy loam	0.55
Kaparda	Bunded levelled	Sandy clay loam to silt loam	0.55
Haryana			
Hansi	Unbunded levelled	Coarse loamy to sandy loam	0.28
	Bunded levelled	Coarse loamy to sandy loam	0.55
Sampla	Unbunded unlevelled	Sandy loam	0.10
	Bunded unlevelled	-do-	Non-uniform with wide variations
	Bunded levelled	-do-	0.70

4 Technology for use of unconventional naturally occurring saline water

Leaching of saline soils: Saline water can be used to leach down the saline soils provided the concentration of salts in the water is less than the concentration of salts in the soil water. To illustrate this issue, a practical exercise has been shown in Table 5. Using layer-wise equilibrium theory of salt transport, which has been tested and field verified, an exercise has been prepared. This exercise is for a saline soil (EC 100dS/m)whose salinity is to be brought down to 4 dS/m using fresh water and saline water of 40 dS/m and 20 dS/m. It is shown that total water requirement would increase by 20%—50% depending upon several combinations that could be implemented. The fresh water requirement, on the other hand, would decrease by 15%—40%. Since the increase in total water requirement is at the expense of saline groundwater, it should help in the use of saline groundwater such that rate of rise of the water table is decreased to that extent.

Table 5 Saving in fresh water as a result of use of saline water in leaching programs

EC of leaching water	C_s-C_i / C_i	Salt leached (%)	Leaching water required	Fresh water required	Total water required	Increase in water requirement (%)	Saving in fresh water (%)
40	0.6	48	1.59	2.70	4.29	34.1	15.6
		54	2.30	2.46	4.76	48.7	23.1
20	0.8	64	1.59	2.20	3.79	18.4	31.3
		72	2.3	1.95	4.25	32.8	39.1
0.0	1.0	96	3.2	-	3.2	-	-

Pitcher irrigation: Sprinkler and drip irrigation techniques are commonly employed to use relatively more saline water for crop production. Since, the initial cost of switchover from surface to these improved techniques is high and beyond the reach of the Indian farmers, a low cost pitcher irrigation techniques has been developed. In this technique, a pitcher (earthen pot) commonly used to cool water during the summer season is used for growing salt sensitive vegetable crops. Without elaborating much on this technology, it is observed that this technology helps in conserving water to an extent of more than 50% compared to the conventional surface irrigation techniques. It also allows the use of relatively more saline water than conventional irrigation techniques. It is shown that saline water even up to 15 dS/m could be used to grow salt sensitive vegetable crops (Table 6, Dubey *et al*., 1991). The data generated in India show that in conventional irrigation, water of 2 dS/m—3 dS/m salinity could only be applied to grow such crops (Minhas and Gupta, 1992). The expansion of such an indigenous technology may help to exploit naturally occurring saline ground water. It would also help save fresh water to expand area under irrigation or to release the water to other sectors.

Table 6 EC of the irrigation water for equivalent crop yield as with fresh water

Crop	Irrigation water salinity (EC, dS/m)
Tomato	5.7
Brinjal	9.8
Cauliflower	15.0
Ridge gourd	3.2
Cabbage	9.7
Water melon	9.0
Musk melon	9.0
Grapes	4.0

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