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ENVIRONMENTAL CONTRIBUTIONS OF SOME TRADITIONAL TECHNIQUES

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/ This paper discusses the positive effects of some traditional irrigation and water harvesting systems of India towards salinity control. Some of these , like the khadin of western India are still surviving. Currently some studies are available which describe how the system survived for hundreds of years in spite of being located in a highly salinity prune tract. Other traditional system like in north India, have been replaced by modern techniques. In their case it is only possible to document the past conflict between farmers and irrigation agencies on this issue and also that certain recent recommendations for salinity control establish the correctness of the old approach. Important lessons may be learnt from studying these traditional systems.}

INTRODUCTION

As per the last estimate, the extent of salt-affected soils in India was 7 million hectares. By now it has probably increased to about 10 mill. ha. (Abrol and Dhruvn Narayana ed.. 1990 : 307). This however, is the area with acute salimtv. The magnitude of the problem is far more severe and a nuch larger part of canal irrigated areas run the risk of turning saline. Bowonder and Ravi (1984) had estimated that 10 million ha of land in the country are waterlogged and about 25 million ha suffer from soil salinity. Kanwar's estimate of areas suffering from different degrees of salinity is about 2O million hectares. It is estimated that the productivity, in nearly 50 per cent of the area under canal irrigation has been adversely affected in varying degrees due to problems of waterlogging and salinity 'Abrol. 1992 : 67).

Three broad types have been identified (Mamoria, 1980 : 148-49 ; Abrol and Dhruva Narayana ed. , 1990 : 319) as salinity prone.

(1) The western part of India is a semi-arid to arid region with hot climate and a dry winter. In this climate evaporatíon is always greater than precipitation. Hence the soil profile development by eluviation is greatly retarded. The soil is marked by concentration of salts - saline and alkaline. Estimated salt affected area is about one mill, hectares.

(2) The marked seasonalitv of rainfall effects salt release over a very large part of the country. In south India and the Gangetic valley warm rainy climate is followed by dry winter. During the rainy season precipitation *is* greater than evaporation which

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induces leaching of soluble salts down the profile. If the water table remains high, the soluble salts will remain in the profile. In northern India, in particular, the salts are transported in solution by the Himalayan rivers which later percolate in the sub-soils of the plains and goes on accumulating in the area of inefficient surface drainage. Thereafter, during the dry season these salts are drawn upwards through the capillary spaces by evaporation from the surface. In many cases salts are deposited on the soil surface showing white or black patches of efflorescence on the soil surface. Impervious sub-soil or hard pan also contributes to the phenomenon. Estimated salt-affected area is about four million hectares, 2.5 in Indo-Gangetic Plains and 142 in the Medium and *Deep* Black Soil Regions of central and southern India.

(3) A very large part of coastal region, about two million hectares are affected by sea tide *carrying* salt laden deposits. The river deltas and estuaries *of* the eastern coast accounts for about 1.4 *mill.* ha. of salt affected areas. Another *0.7 mill* ha. is found in the arid Gujarat coast. Large parts of sen coast are also subjected to periodic inundation by tidal water. This is particularly noted in the western coast.

In dealing with problems of salinity two types of solutions are possible : preventive and curative . Current stress is on curative methods. These include : (1; chemical treatment. 2) vegetative and biological measures and (3) a combination of the two. The former *is* input intensive but results are obtained in *ihe* first year. The latter *needs* 3 to 4 years gestation period. In forty years, till 1989-90 the state of Uttar Pradesh was able to reclaim 157.036 ha. at land which accounts for only 12 per cent of the total saline area in the state (Arora. 1994). With increasing, alarm lately. programmes have been accelerated. Since gypsum *is* available in abundance in Bajasthan state. neighbouring the Indo-Gangetic saline belt, and since the State governments subsidise it heavily (in Haryana. subsidy is 75 per cent of cost' farmers often adopt the chemical treatment. But is it a sustainable solution ? Newer and newer areas will come under salinity and more and more of these costly and heavily subsidised activities will have to be performed.

That is why the long-term preventive solutions are important. Preventive efforts require thorough understanding of the reason and preventing it. It is here that the traditional method of maintaining the ecological balance for centuries will be of crest relevance even in the present period. In the next sections we will introduce the outlines of some of these traditional methods and discuss the soundness of their scientific principles.

PREVENTIVE AND CURATIVE USES OF RAINWATER

.. However pure irrigation water is. it always contains some salt. Salts are added to the soil with each irrigation. Crops remove much of the applied water from the soil to meet its evapotranspiration demand but leaves most of the salt behind. At each irrigation more salt is added. Hence a portion of the added salt must be leached from the root zone before the concentration affects crop yield. Leaching is done by applying sufficient water so that a portion percolates through and below the entire root zone carrying with it a portion of the accumulated salts. After many successive irrigations. the salt accumulation in the soil will approach some equilibrium concentration (FAQ, 1985). A successful water management is to keep the equilibrium level within a certain limit which is best for crop growth.

This equilibrium level is decided by three factors (FAO, 1985) :

(i) the salinity of the applied water
(ii) depth of water leached below the root zone
(iii) depth of water applied at the surface

A good salinity management strategy should take care of all the three factors. Apart from the law salinity of rainwater the application methods of different rainwater harvesting systems contribute towards determining the equilibrium level of salt content.

The quality of river waters in India, unless contaminated otherwise, are of a very high order (Gupta. 1990 : 19-26). Canal waters originating from the rivers or their reservoirs as the main source, represent the parent rivers in quality, unless contaninated otherwise. Yet, however good may canal water be as leaching agent.

Table - 1

AVERAGE ANNUAL RAINFALL IN SALT AFFECTED AREAS

regions	annual rainfall (in cms.)
Indo-Gangetic Plains :	
(i) alkali soils with sweet groundwater	55-100
(ii) alkali soils with sodic groundwater	50-55
(iii) saline soils with moderately saline groundwater	100-140
Medium and deep black soil region :	
(iv) alkali soils with sodic or saline groundwater	70-100
Arid and semi-arid region :	
(v) saline soils with highly saline groundwater	below 50
Coastal areas :	
(a) arid zone of Gujarat	below 30
(b) deltaic (1) W.Bengal, Orissa,	140-160
(2) A.P. , Tamilnadu	70-90
(c) sea water ingress. e.s-Kerala	200-300
INDIA AVERAGE	113

source : Abrol *and* Dhruva Narayana ed. , 1990 : 309-310 rainvater is certainly the best. Composition varies as one moves away from the sea, depending on local pollution sources and from shower to shower. But overall, the rainwater has an EC range between 5 to 50 US cm^{-1} (Gupta, 1990 : 16) compared to some 200-300 US cm^{-1} common in canal water. Thus the equilibrium concentration of salt accumulation in the soil attained after many successive irrigations, is lower if the leaching agent is rainwater in comparison to use of canal water. For partial leaching to attain tolerable limits for crop growth, less amount of water is necessary if the leaching agent is rainwater, not canal water. This in turn, contributes to the reduction in problems of waterlogging in areas having drainage problems.

Gupta (1990 : 264-273) made some rough estimates of salt balance and leaching requirements. He found that in monsoon countries, when the rainfall is short and concentrated, rainwater may be sufficient to leach out salts from the root zone. Without going into the details let me draw attention to the rule of thumb that he developed. "The depth of soil from which the soluble salts (> 8O per cent of it) may be leached during the monsoon season, corresponds roughly with total rainfall during the monsoon season" (Gupta, 1990 : 270). Thus, if the root zone depth of the soil is 40 cm. front which accumulated salts are intended to be leached, a minimum amount of rainfall equal to 40 *cm*,. is necessary. The actual requirement will vary depending on the texture of the soil and other percolation considerations. Still, this gives an Idea. The following are the average annual rainfall of the salinity prone areas of India (Table -1) . It must be evident that rainwater is available in plenty for effecting high proportion of leaching almost everywhere in India.

While discussing suitable strategies for using saline water for irrigation Gupta (1990 : 270) had favoured maximum utilisation of rainwater for two reasons :

(i) it has a modifying effect on the number of irrigations required to meet the *evaporative* demand as part of it is met by rainfall and

(ii) it helps in leaching of accumulated salts, because it is the best quality water available for leaching.

A close look at these two principles will establish that they are valid not merely for the limited objective Gupta had set for himself, but in general too. 8ecause of these considerations, maximum utilisation of rainwater must be the most desirable strategy for salinity control. Indeed, this was so in the traditional set up. Colonialism and modern extension programmes had failed to grasp these principles and had done enormous damage to the agricultural land. Even now, it is necessary to honour these principles. We will discuss some traditional techniques of India from this perspective.

INDO-GANGETIC PLAINS

If water influx in the substratum is greater than water expenditure [I > Q] then the groundwater level increases and waterlogging occurs. The water influx in this area is very high because of heavy annual rainfall and an enormous amount of snowfall carried by the Himalayan rivers flowing through this region. The first priority therefore, is to drain out the excess water. The traditional method facilitated drainage - both by horizontal and vertical methods. The natural drainage lines were never interfered with, leave alone directing them inland through canals. Besides, the

major mode of irrigation was wells, which provided vertical drainage. Fortunately, most parts of this region has sweet groundwater.

Natural precipitation was retained (Whitcombe. 1971 : 6) in water harvesting structures like tanks and ponds (called *jhils* - surface depressions filled by summer rains). The jhils were reported to supply some amount *of* irrigation water and produced forage (Stone, 1984 : 140). Indirectly too, they must have contributed significantly by enriching subsoil moisture. Recharging of groundwater was an important factor. Although rainfall is high in this region it is highly variable and irrigation is absolutely essential during summer and drought. Finally, the tanks and ponds ensured the supply of the best leaching agent, rainwater, in this salinity-prone area. Canal construction techniques were not unknown but rarely used. The best known canal is the western Jamuna canal constructed in the sixteenth century by the Delhi Sultanate, probably imitating west Asian models. The canal had fallen into disuse and had inspired the British engineers to undertake canal construction.

Nineteenth century construction of canals and distributaries in U.P. did not follow the watersheds and interfered considerably with natural drainage lines. The railways and roadways too had no consideration for the drainage systems (Stone, 1984 : 134-135). But the need was felt badly after occurrence of severe floods, waterlogging, salinity and malaria in canal irrigated tracts of U.P. As the problems of salinity aggravated investigations began. By late 1860s causes were known and a couple of experimental leaching and drainage stations were established. However, the results were not encouraging. A Committee (Reh Committee. 1S73) was appointed whose report reflects the unassailable contradictions faced by the government (Whitcombe. 1971 : 76-79 ; 285-289). The Committee could not admit what was clearly evident from all available information — that introduction of canal irrigation itself was the basic mistake. For heavy water influx the. Committee laid the blame on the farners' practice of overirrication. suggested raising of water rates to achieve greater economy at water and recommended continuation of the reclamation experiments. The Reh Committee had also recommended. albeit reluctantly, that lift irrigation should be substituted for flush irrigation. In order to open the market the Canal Department had earlier offered flush irrigation at lower rates than the existing lift irrigation (Whitcombe, 1971 : 9). Gravity irrigation from canal was touted as replacement for the dreary old water lifting (Whitcombe, 1971 : 78). So it was a reluctant admission. In any case, the government could not further raise the already high water rates. This had set the course of salinity control efforts. The leaching and drainage experiments, though unsatisfactory, became the only implementable policy. The preventive efforts could extend only that far, not up to a fundamental reconsideration of canal policies.

The old rainwater harvesting systems could not survive the pressure of canal irrigation. The interference with the natural drainage systems wrecked havoc on them. Stone (1934 : 135) describes a case where the original system used to drain flood water into a rivulet after flowing through two *jhils*. After the construction of _a canal within a few years the water levels of the jhils increased inundating surrounding land, throwing them out of the cultivable category. After the drainage channels were dug, numerous complaints were made by farmers that the drainage system was drying out the country excessively. Often their canal supplies were diminished. Besides, the Jhils etc. which stored rainwater were rendered dry for about nine months a. year (Stone, 1984 : 140). Indeed, it was so excessive that watertable of places thirty mile- -TUBE WELL. Some twenty years later, following serious drought, when tubewell irrigation was being considered, some officers felt that the policy of surface drainage has been carried too far. The subsoil water level is lower than it was twenty years ago and have a permanent tendency to fall (Stone , 1984 : 141). Following destruction of rainwater harvesting structures canal irrigation remained the only source of recharging groundwater. Wherever canals went, well-digging was often made impracticable by the rise in the water table. So the farmers had little choice but to adopt canal water (Voelcker, 1893 Whitcombe: 69 ; be. 1971 : 80-31). Table -2 shows the extent of destruction of rainwater harvesting structures as reflected in official statistics. The data about them are included under two heads ; 'tanks' and 'other sources'. We have grouped them together. The choice of the two years are guided by data availability and comparability of district boundaries before administrative reorganisations.

Table-2

Changes in Irrigation pattern between 1901 and 1974
Some districts of present Uttar Pradesh (U.P.)

Addition in land use between 1901 and 1974 (in '00 hectares)

District	Irrigated: Tank Other Sources	Irrigated: Canal	Irrigated: Total Surf. Water	Irrigated: Well	Irrigated: Tube Well	Irrigated: Total Ground Water	Tot. Irr. Land	Tot. Unirr. Land	Net Sown Area: Actual	Net Sown Area: % of Addn.
Bara Banki	-418	[illegible]	[illegible]	-722	[illegible]	5	[illegible]	- [illegible]	-55	- 7
Sitapur	-149	591	445	-375	771	75	544	- [illegible]	-37	- 1
Rae Bareli	-237	452	254	-516	171	-345	17	257	276	15
Unao	-215	803	592	-458	183	-275	257	- 37	258	9
Lucknow	-132	385	253	-169	157	- 11	242	- 258	-27	- 3
Basti	-550	183	-163	-332	1269	937	774	- 372	502	10
Jaunpur	-102	106	4	-359	595	235	239	165	404	16
Allahabad	-270	429	158	-350	707	357	515	- 63	453	11
Budaun	- 71	0	- 71	385	891	1276	1205	-1129	66	2
Bareilly	-112	44	323	95	305	400	723	- 638	91	3
Comparison is difficult due to addition in net sown area:										
Mainpuri	- 68	247	179	-272	1045	773	952	-463	490	31
Pilibhit	-128	392	265	-138	374	236	500	15	516	33
Fatepur	-219	290	71	- 41	261	229	291	306	597	27
Azamgarh	-523	335	-118	-672	1205	532	345	774	1118	36
Kheri	- 96	147	51	-146	512	366	417	430	847	24
Sultanpur	-259	436	176	-227	296	8	185	376	561	22
Partabgarh	-254	430	146	-341	96	-245	- 99	548	449	22

Source : Indian Agricultural Statistics, Govt. of India.

"Large scale implementation of drainage programme in U.P. began only since the 1830s, when a series of wet seasons created serious waterlogging problems and prompted an outcry against canals (Stone, 1934 : 139). By 1900 the aggregate surface drainage channels constructed were more than a third of the total length of canals and distributaries (Stone, 1934 : 134-145). The old irrigated areas settled to new equilibrium levels after several years. Later, after the introduction of tubewells and power operated pumpsets vertical drainage too has been a possibility. These have solved *n.* part of the problem, but only *a.* part. As yet, little has been done to provide proper drainage in canal irrigated areas. The problem continues and the threat of waterlogging and salinity becomes more and more acute.

CENTRAL AND WESTERN REGION

Salinity is also found in large parts of Gujarat, Madhya Pradesh. Maharashtra, Karnataka. Rajasthan and Andhra Pradesh. The soil characteristics hero differ-from that of the Indo-Gangetic pattern which need different set of considerations. Both saline and alkali soils are found depending on the aridity of the region. But we need not distinguish between them, for, our concern is prevention of salt deposits in any form. In leaching of salt concent one has to consider that the soils of this region in general, have slow water infiltration and percolation rates and water diffusivitv. Substantial part of this region consists of medium and deep black soil (vertisols) which tend to have a positive water balance fluctuating between shallow depths. Any additional salt carried in by canal water tend to accumulate. Since digging, laying and maintaining is difficult in this soil the scope of drainage is limited. Groundwater is sodic or saline and therefore, vertical drainage possibilities are also ruled out. Because of slow water diffusivitv, soil degradation process in this region is slow. Only as time passes and in compete absence of leaching, salt content increases sizably in the surface horizon . But once it appears it as difficult to get rid of. Projects like Nagarjunasa and Srirasagar in Andhra Pradesh. Tungabhadra in Karnataka. Tawa in M.P. and Indira Gandhi canal in Rajasthan are only some of the major ones which are suffering from salinity problem.

The traditional system chat was extensively used until some three decades back was that of "submergence tanks". This is basically *in situ* water harvesting. The undulating topography allows for the construction of above-surface tanks. Although gravity irrigation may be performed that was rarely practised in the black soil region. The *Bundhies* or submergence tanks retained water practically throughout the rainy season. After the rainy season water used to be drained out and the bed was used for cultivation. Sometimes river floods were diverted to feed the submergence tanks. They consisted of embankments with heights neither as great as the above-surface tanks nor as low as field boundaries. Submergence tanks did not provide gravity irrigation. Instead, the bed. rich in subsoil moisture, was cultivated. They also need to be distinguished from *in situ* storage. In one, cultivation follows submergence and drainage, in the other they occur simultaneously (Sengupta, 1993).

Submergence techniques were basically conservation of moisture by contour bunding in the water-shed itself. Storage of fresh rainwater for months over the whale watersheds could effect some amount of leaching. This was the perfect answer to extremely slow water infiltration and percolation properties of the soil. At the sane time the admirable water-retention capacity of the soil was used to devise a more efficient method of water utilisation than gravity irrigation. Submerging also helped in soil conservation. The concerned area is prone to severe soil erosion.

Until a couple of decades back, the submergence technique was extensive all over the *haveli* tract of M.P. A century ago it was found all over the western region. Reference to the *sailabi* system of Punjab is found in old official records. It is still a recognised system of irrigation in Baluchistan where it is known as the *sailaba*. system (Oesterbaan, 19S3). Although the system might have covered, at a rough estimate. a million hectare or more, and had at one time, received government: patronage, recent information regarding them are not found in official irrigation statistics in India. Surprising though it may appear, the reasons for this omission are not within the scrips of this paper (Sengupta. 1993 : 27-29). In essence, the reluctance to consider rainwater harvesting structures as irrigation, is at the root of such ignorance.

Recently, one submergence irrigation structure, found in the midst of Thar desert and called *khadin* , have drawn considerable attention. The *khadins* of Rajasthan. though provide surface irrigation in years of good rainfall, are utilised primarily for subsoil storage properties. *Khadins* are found even in the heart of Thar desert. The old khadins have been found "to be site-specific systems. The soils of *khadins* are medium to fine in texture, with good water-holding characteristics as against the loose, sandy, droughty soils or the rest of the desert. These soils remain wet or moist for a long period, and are favourable for chemical weathering of soil minerals and for microbial activities. The temporarv water table that is formed in *khadins* after collecting precipitation over the catchment area, slowly recedes into the subsoil and substrata during winter, thus continuouslv supplying moisture to the deep growing roots of the crops throughout its period of growth. Depending on the good or bad rainfall in 1 year either gravity irrigation or bed cultivation is practised in a khadin. It is reported that khadins succeed in producing it least one *crop* even if the rainfall in a vear is one-third that of normal.

The amount of run-off collected in a khadin depends on the extent of the catchment area, which *is* about 12 to 15 times that of the service area 'Kolarkar and Singh, 1990). The region being a particularly saline tract, the rainwater harvest would contain some salt by leaching out their wider catchments. In course of time the salt will accumulate in the profile and turn the land unusable. Khadins however, have remained functional for several centuries. Intrigued by this fact, the soil scientists of Central Arid Zone Research Institute have conducted on this system one of the rare studies of salinity control in traditional systerns. They ("Singh and Kolarkar. 1933) show that there is not much salt accumulation inside the khadin. but heavy deposits are found just outside where water from seepage passes out. Obviously, the incoming salts are continuously expelled. Their explanation is that the sediments accumulating inside the khadin gradually raise the bed level. It reaches in old khadins between 0.25 to 1.00 metre. In consequence, the hydrostatic pressure of water body of *khadins* push the salt content out, which deposits on the outer side of the embankment.

COASTAL REGIONS

Saline soils of delta and coastal regions include Ganga delta or Sunderban. Mahanadi. Godavari, Krishna, Cauvery and small river deltas in the east coast and the estuaries of Narmada and Tapi in the west. Here, both prolonged waterlogging and sea water intrusion create problems of salinity. Besides deltas and estuaries marine cycles also affect sea water ingression in many coastal areas. These include the lagoons of Kerala, *khar*, *khajan* and *kale* lands of western coast extending from Gujarat to Kerala and the Rann of Kutch. In the east coast, salinity due to sea water ingression is less, but saline delta regions abound.

In general, in these areas horizontal drainage is not possible. Saline water ingress need to be prevented first by constructing sluice gates and protective embankments. Thereafter salts present on the surface can be flushed out with stood quality water. Fortunately once again, most parts have good quality water. Rainfall is generally very high (above 140 en) in the specific regions or on the hills nearby as in the western coast. In the past rainwater used to be stored in shallow ponds within protective embankments. This system of cultivation of rice was extensive in West Bengal *(bheris)*, Orissa , in *kharland*, *khazan* and *kale* cultivation in the west coast. In the modern phase too the same principle is being followed with improved structures.

The southern part of the east coast and the Kutch peninsula are the only coastal regions not favoured by heavy rainfall. In these deficient rainfall regions the Groundwater too is saline. But the salinity of the coastal soil is so high that the river water is good enough for sufficient leaching. In the low rainfall regions of Krishna or Cauvery delta, with good river water supply, canal irrigation used to be practised extensively in the past. It is only in these parts of the country that canal irrigation had developed extensively even in the pre-colonial period.

Data shows that in Kutch and Saurashtra region there were thousands of small tanks in the past. Whether this was one of the purpose of those tanks can be decided only after knowing their exact locations - which is beyond the capability of the present author.

CONCLUSION

It is neither possible nor desirable to go back to the pre-modern situation by writing off the networks of canals and other structures. But the traditional principle of using rainwater as much as possible is also confirmed by modern research. Along with drainage, embankments or long duration storage wherever necessary, these principles need to be resurrected in order to find *a* sustainable solution to the everwidening problems of salinity. This imply a thorough reappreciation of irrigation system design. However daunting it may seem, irrigation technology today needs thorough reappraisal from many aspects other than that of civil engineering.

Rainwater harvesting systems have mostly been seen as small scale or "minor irrigation" systems - as per Indian terminology. Seen in the above perspective, they are not. The well-laid network of tanks and ponds in the Indo-Gangetic plains used to share between them, the whole of the run-off flowing through each watershed. Submergence tanks used to be constructed in series and they could appropriate every bit of run-off after a flood in the adjacent rivulet. The coastal ponds would not be successful unless a whole series checks sea water ingression along a long stretch of coastline. When appreciated from this perspective the whole design will seem to be a major irrigation system. Indeed, this is a kind of design which has the potential to compete with modern multipurpose river valley projects. They deserve to be developed along this line.

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