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CHALLENGES AND SOLUTIONS OF PROVIDING IRRIGATION IN SALINE SOIL: CASE STUDY OF SARADAR AROVER PROJECT, GUJARAT, INDIA

TITLE FRENCH (LEAVE AS IT IS IN CASE NO TRANSLATION)

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ABSTRACT

Food security has been a major concern at the world level. Countries with dense and large population have a more serious concern. India has limited land and water resources but a large population and therefore needs to utilize every possible piece of land available for agriculture. Besides limited land and water resources, being a peninsular country it faces a lot of issues like saline coastal land and salinity ingress along with poor drainage characteristics. All the challenges considered, India needs to attain optimal use of land resources and water resources and still needs to attain and maintain food security. Sustainable irrigation and agricultural practices are the only solution. India is looking forward to attempting for the said accomplishments. So far India has not been able to utilize the available land resources for the purpose of agriculture and is struggling to do so. Perhaps enhancement in water use efficiency and overcoming techno-economic and topographical challenges could improve a lot. The paper outlines the overall scenario of India and in its context the situation of Gujarat. India's accomplishment in food production in spite of its not being able to utilize all the available land resources for agriculture is also discussed along with the role of irrigation therein. Gujarat has the longest sea coast amongst all the states of India and the issues are the worst. Sardar Sarovar Project of Gujarat is meant for providing protective irrigation water to the challenged areas of the state. Therefore, region-specific strategies have been worked out in different agro-climatic zones. The process is really very complex and needs several local aspects to be considered. All these have actually made the project the life line of the state. The paper focuses on the situation of one such coastal area name by Bara Tract located in Bharuch district of Gujarat and discusses as to how serious issues of that area have been addressed and are being addressed and what kind of results have been obtained. Results of socio-economic study of pre-irrigation social condition of the habitants and post-irrigation have also been succinctly put forth. Socio-economic condition of the area in which the irrigation water is supplied drastically changes if sustainable practices are resorted to. Bringing prosperity to the people has been the actual goal of irrigation and agriculture which is very difficult to attain in the saline areas as only restricted irrigation is required to be provided during specific time and with limited options of cropping pattern. Sensitivity is high on every parameter and therefore irrigation management in such areas is a real challenge. Optimizing benefits amongst several constraints needs a combination of technological appropriateness and congruent agricultural practices with deep involvement of the farmers. Interdigitating the technological aspects with social conditioning is the key to success in such situations. Objective of the paper is to shed light on multifarious aspects to be taken care of while attempting at achieving long term goals in coastal saline areas by citing an actual case study. Such efforts in other areas

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could help attain food security of a higher level and at the same time can help attain sustainable developmental goals.

1. Food security in India: accomplishments and Challenges

Since independence (from British-rule) in 1947, India having the second biggest population in the world, faced two key economic challenges - achieving food security and alleviating poverty. Because of India's geographical and social conditions, agriculture was viewed as a promising domain for effectively addressing the issue of food security to a great extent and partly the issue of poverty. India gave the top most priority to food security and food grain production in the post-independence period and accordingly the five year plans were devised. In spite of serious flaws in implementation of them, India could attain self-sufficiency in production of food grains from a state wherein their import for feeding crores of people was the only way.

From a mere 50 million tons of annual food grain production in 1950s, India produced 277.5 million tons of food grains in the year 2017-18.

Table 1. Production of Food Grains in India

Year	Food production (million tons)
1950-51	50.8
1960-61	82.0
1970-71	108.4
1980-81	129.6
1990-91	176.4
2000-2001	196.8
2011-12	257
2017-18	277.5

Area under agriculture got increased from 132 Million Hectare in 1050-51 to 199 Million Hectare in 2010-11 which is apparently a small achievement.

Table 2. Area under Agriculture in India

Year	Area under Agriculture (million hectare)
1950-51	131.89
1990-91	185.74
2000-2001	185.34
2009-10	188.99
2010-11	198.97
2014-15	198.36

In production of food grains the yield has played a major role. Total yield of all the food grains was 5.22 quintal/ hectare in 1950-51 which escalated up to 21.53 quintal/ hectare in 2016-17. Almost all the food grains have witnessed a fourfold rise in the yield. Yield of rice was 6.68 quintal/ hectare in 1950-51 which got increased to 25.5 quintal/ hectare in 2016-17. Yield of wheat was 6.63 quintal/ hectare in 1950-51 which got increased to 32.16 quintal/ hectare in 2016-17. All the food grains have shown steady rise in yield which finally became a boon for India.

Table 3. Crop Yield (Quintal/ Hectare)

Crop	1950-51	1990-91	2000-01	1010-11	2011-12	2016-17
Rice	6.68	17.4	19.01	22.39	23.72	25.5
Jowar	3.53	8.14	7.64	9.49	9.54	8.89
Bajra	2.88	6.58	6.88	10.79	11.56	13.11
Maize	5.47	15.18	18.22	25.4	24.76	26.64
Wheat	6.63	22.81	27.08	29.88	31.4	32.16
Coarse Cereal	4.08	9	10.27	15.31	15.93	17.84
Gram	4.82	7.12	7.44	8.95	9.12	9.73
Tur or Arhar	7.88	6.73	6.18	6.55	6.56	8.85
Total Pulses	4.41	5.78	5.44	6.91	6.94	7.79
Total Food grains	5.22	13.8	16.26	19.3	20.59	21.53

Area under agriculture and yield - both witnessed a steep rise and therefore per capita net availability of food grains went up from 144.1 Kg/ year in 1950-51 to 177.9 Kg/ year in 2016 in spite of fourfold growth in population.

In spite of huge achievements in the domain of food security, further way to ensure the sustainability is full of challenges. Table-4 shows the land use details of India which suggests clearly that out of 328.83 Mha (Million Hectare) land, the net area sown is approximately 142 Mha out of which only 58 Mha is sown more than once a year. Net irrigated area is 68.38 Mha and irrigation potential created is little more than 100 Mha. Thus, all the available arable land has not so far availed water resources in spite of constant implementation of the modern methods of irrigation and exploring almost all the feasible sites. So far whatever has been achieved has been by resorting to productive irrigation by bringing maximum possible arable land under reliable irrigation and by increasing the crop yield.

Table 4. Land Use Details of India (Million Hectare)

Geographical Area	328.73
Forest	71.79
Not available for cultivation	43.88
Other uncultivated land	25.83
Fallow Land	26.18
Net area sown	142.02
Net Irrigated Area	68.38

The problem definition is very clear for India – it is the locations of water availability where all the utilizable arable land should be used for agriculture rather than identifying suitable soils for agriculture and to provide water resources to them. Constraint is the locations of water resources that would govern the planning. Now that almost all feasible sites for big reservoirs have been explored, the only doable act is to construct small reservoirs and tap their potential for the balance land which would be protective irrigation rather than productive. This strategy is to optimize the benefits from the available land and water resources within given natural constraints. In both the scenarios – productive irrigation and protective irrigation, common activity would be to utilize whatever soil that could be brought under irrigation irrespective of its quality. In other words, the soils of inferior quality might be required to be irrigated since it is feasible to provide some little water there rather than selecting the best quality soil for brining under irrigation. This is what practicability and pragmatism calls for.

But the said strategy inherently contains some challenges. Some soils which could be utilized for agriculture with some irrigation made available but its inherent quality would not ensure sustainability of agriculture with irrigation. If such challenges are not prudently considered while chasing the goal for food security, it might pose unsurmountable challenges in future. Thus, the situation is very complex in India.

2. Soil Characteristics of Gujarat and Sardar Sarovar Project

Soils in Gujarat are grouped in to six broad types i.e. (i) deep black (ii) medium black, (iii) coastal alluvia, (iv) alluvial loam, (v) alluvial sand and (vi) desert sand; for the purpose of planning command areas of irrigation projects. Each of the above types have different characteristics from agriculture and irrigation points of view. Another problem with Gujarat is of sea water intrusion as it has 1664 Km long sea coast. Groundwater extraction in want of surface water aggravates the same. Besides that, the soil salinity has been witnessed in the interior land in the recent past which has paused a serious threat to agriculture in the state. Sodic soils are in many parts of Gujarat state. Over irrigation has been the cause in some areas, irrigation by saline groundwater extracted from deeper aquifers has been the cause in some areas and overuse of chemical fertilizers has been in many areas. The soil salinity map of Gujarat state shows that interior areas have been seriously affected. The saline areas are increasing with passage of time. Existing irrigation projects are also affected due to this issue.

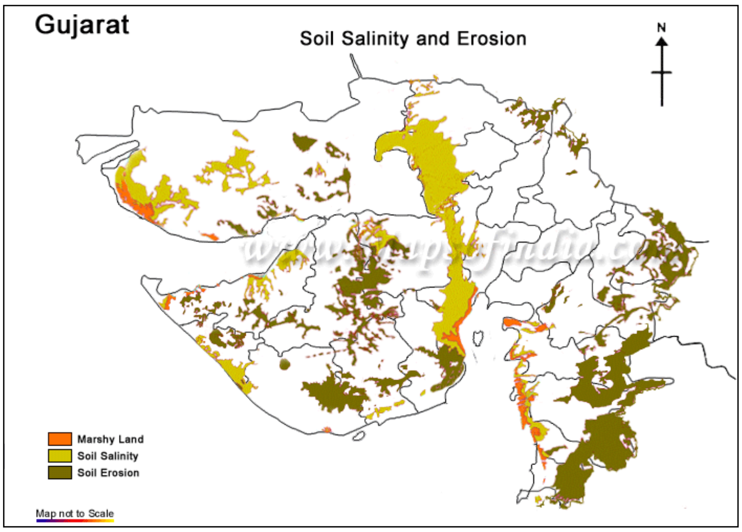

Figure 1. Soil salinity and erosion map of Gujarat

Sardar Sarovar Project (SSP) – a mega project of Gujarat state of India is one of the largest projects of the world with 1.8 million hectare of command area. It has a 75,000 km long canal network for irrigation command and to address a large encompassment of 9600 villages and 135 towns for supply of domestic water. It has been designed with protective irrigation or supplementary irrigation approach rather than full irrigation approach. Average annual delta designed in the command area is 42 cm. The objective is to promote water saving crops and conjunctive use of water wherever possible. As most of its command area has some or the other problem related to soil and topography, limited delta is advisable.

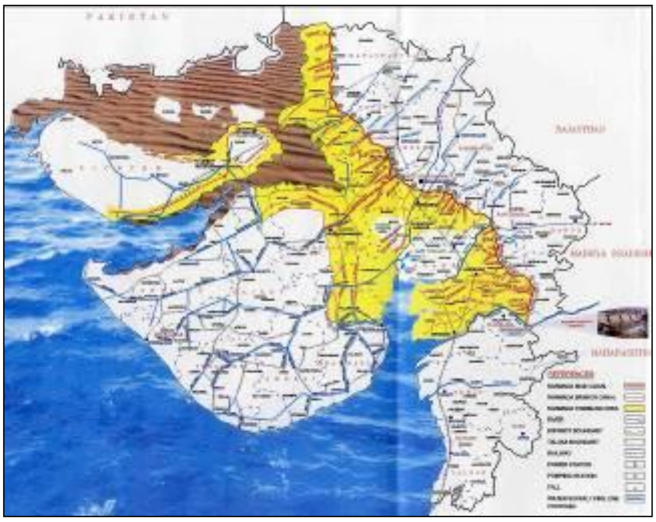

Figure 2. Sardar Sarovar Project, its canals system and command area

Planning of command area of the SSP has been made considering many constraints. Canal network of the SSP traverses several problematic soil stretches besides saline soils. Drainage condition also varies across the command area. There are four drainage zones in which the command area is classified. Drainage Zone-IV means the most problematic one from drainage point of view. As per the design philosophy, with respective precipitation pattern and drainage mechanisms providing 2 l/s/ha design discharge in heavy soil, it would take 5.3 days for inundation to be sorted out in areas under Zone-IV.

Thus, many parameters were required to be considered for classification of different parts of the command area and proper agro-climatic zonation was introduced at the planning stage. Large command area has been classified in to 13 regions based on parameters like annual rainfall, land irrigability class including drainage characteristics, groundwater quality and quantity, cropping pattern, alignment and the command of major branches, etc.

3. General strategy for irrigating challenging soils

As a standard practice, six irrigability classes of soils are followed as the basis of command area planning in India. In planning of the command area of the Sardar Sarovar Project, the same methodology was adopted. As per irrigability class the cropping pattern and the delta to be served were decided.

Irrigation strategy is devised considering irrigability class of the respective area. Further zonation is made according to type of soils within the area under each irritability class and then the exact irrigation planning is made. This is how sustainability of agriculture is tried to be achieved.

Table 5. Irrigability Classes

Class 1	Lands that have few limitations for sustained use under irrigation
Class 2	Lands that have moderate limitations for sustained use under irrigation
Class 3	Lands that have severe limitations for sustained use under irrigation
Class 4	Lands that are marginal for sustained use under irrigation because of very severe limitations
Class 5	Lands that are temporarily classified as not suitable for sustained use under irrigation
Class 6	Lands not suitable for sustained use under irrigation

3. Bara Tract – a region with complex challenges

Command area of the SSP has been divided in to 13 regions as per agroclimatic conditions, cropping patter and irrigability. Out of 13 pre-defined regions of the command area of the SSP, Region-4 includes an area known as Bara Tract which is in Bharuch District especially Jambusar, Amod and Vagra Talukas (Blocks). It covers 1,11,000 hectare of Gross Command Area. This region occurs on nearly flat lands with slope gradient of 1:2800-4500 or more. It is also characterised by poor out fall and out flow conditions. The region experiences a tropical climate. The maximum temperature rises up to 45 °C in the month of May. The average annual rainfall is 737 mm. The topography is flat and on the coastal side is only slightly elevated above the highest tide.

Main crops sown in this area are cotton, wheat, pulses and fodder. Cotton is the most preferred Kharif crop in the area. When rainfall is timely and not excessive, the area under cotton is high. In years when the rainfall is high or there is flooding due to run off from the upper region and hence the cotton crop is either damaged or not sown, the land is kept for wheat. Jowar (Kharif i.e. monsoon and partly Rabi i.e. winter) is cultivated for fodder and grain. In some areas gram is also sown in Rabi. Rabi crops are raised on residual moisture.

Because the soil is clayey, swelling pressure is another problem. It varies from 0.65 Kg/ cm^2 to 2.7 Kg/ cm^2 which is unusually high and not suitable for construction of canals. Swelling and shrinkage due to presence and absence of water destroys the canals if are not constructed with proper technology.

Soil characteristics suggest that Bara Tract is saline Vertisol with moderate alkalinity and low hydraulic conductivity. As water absorption property of soil in Bara Tract is not favorable, when rainfall occurs soon after irrigation, inundation for a long time becomes the real threat. This also results in to salt efflorescence and hence the most important question at the planning stage was that whether to irrigate during Kharif or not.

Canal irrigation in sodic soil leads to a very complex phenomenon. Desalinisation of surface horizon due to leaching of salts and accumulation in the lower horizon of the soil profile is generally noticed when canal irrigation is made in sodic soils. With application of canal water, sodic clays may be hydrolysed and therefore alkalisation and a dispersion of the aggregates which could reduce hydraulic conductivity and increase the bulk density which means the soil would be hardened. On the other hand, if canal irrigation is not provided, erratic rainfall would compel the farmers to use the groundwater for protective irrigation. Groundwater here is saline with average Electrical Conductivity as 10.6 dS/m. Groundwater salts contribute to secondary soil salinity which is also dangerous. Thus, rain-fed agriculture is not reliable and irrigation either by canal water or by groundwater has a specific negative impact. Reclamation and management of such soils is a challenge.

4. Solution implemented in Bara Tract

The issue of Bara Tract is addressed by a two-fold strategy. One essential aspect of irrigation strategy is that without attempting to reclaim the lands which are not cultivated, water is supplied to relatively better patches of this area and the other aspect is that frequent but small quantity of watering is made available.

Consistent with restricted use of water, a simple network of water distribution system is devised. Annually 3 to 4 waterings of 8 cm each leading to total delta of 28 to 34 cm is envisaged. The cultivators of this area are very much aware of the limitations of the land and prefer limited irrigation as per need rather than regular flow irrigation. Unit of planning is sub-chak of 12 to 15 hectare. Rotational distribution system is adopted. Limited irrigation water avoids harmful effects on the saline soils and also require use of some groundwater to fulfil the total requirement and hence conjunctive use is naturally adopted by the farmers. Conjunctive use of water i.e. blending of canal water and groundwater, would result in to lowering of the EC value of the groundwater and hence would minimize the negative impact of canal water and groundwater, both i.e. sodicity hazard and salinity hazard.

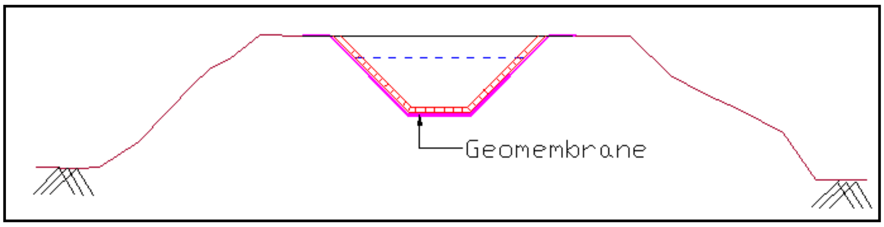

Figure 3. Application of geomembrane

Addressing seepage from canal network is also very important as seepage could add to the severity of drainage issues in saline Vertisols. Moreover, swelling soils swell while come in contact with water and shrink when there is no water and therefore lining gets broken and embankment badly damaged due to piping. In order to avoid all such issues, effectively checking the seepage is the only way. Geomembrane has been used in most of the canals in Bara Tract to ensure complete imperviousness of the lining to check the seepage and swelling and shrinkage related issues.

5. Assessment of effectiveness of irrigation in Bara Tract

It was observed that the condition of the canals remained very well and maintenance issues were almost minimized. Overall efficiency of the canals was found satisfactory. The canals were required to be run continuously for frequent but small waterings and hence the operational difficulties were really there with the project authorities. The canal irrigation was started in 2004 and restoration with proper technology was done in 2010 and 2011.

Detailed characterisation of soil profiles occurring at village Vagra of Bharuch district in Gujarat under pre-and post-canal irrigation situation was carried out to study the effect of irrigation. Salt accumulation was observed in surface layer when saline tube well water was used for irrigation to cotton crop on saline Vertisols. The development of secondary salinisation was observed in the soil profiles irrigated with saline ground water. The same soils when irrigated with fresh canal water for wheat cultivation, showed reduction in soil salinity. The electrical conductivity of saturation extract (ECe) reduced to 0.65 dS/m from 9.8 dS/m in the surface layer, depicting desalinisation. It was also noticed in canal irrigated soils that exchangeable sodium percentage (ESP) increased to 17.2 from 7.8 in the lower horizon which indicated the initiation of pedogenic process *i.e.* sodification. This study was completed in 2018.

From side of the farmers the results were required to be evaluated. A third party socio-economic survey was conducted through a non-governmental organization in 2011-13 for the said purpose whose outcomes are summarized below.

(1) Cotton has been the main and dominant Kharif (monsoon) crop in this area since long but from the point of time the irrigation was made available, it has significantly improved on all important parameters like area covered, yield, income etc. Because area covered under cotton has increased from 46 % to 52.6 % and at the same time yield has also increased from 968.75 Kg/ ha to 2259.16 Kg/ ha, annual income has also witnessed a phenomenal rise of Rs. 70977.8 per hectare. Wheat has been the main crop in Rabi and it has also attained the same trend.

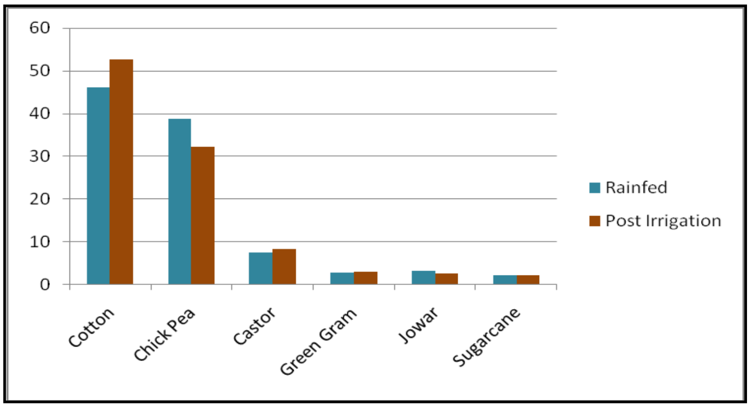

Figure 4. Percentage area covered in Kharif (monsoon) cropping

Table 6. Annual income from livestock (Indian Rupees)

	Pre-Irrigation	Post-Irrigation
Cow	-205	7050
Buffalo	10475	13241

(2) Animal husbandry has undergone significant improvement in the post irrigation scenario. Cows were not economically viable kind of livestock earlier in this area but the changed scenario in post-irrigation phase suggests a remarkable change; buffalos have become more profitable in the changed scenario.

(3) Overall scenario in the sphere of rural agriculture has undergone much change and that has induced positive changes on household expenses meaning thereby proper

irrigation strategy combined with technological solutions adopted has worked well and made it possible to make proper use of coastal lands which otherwise was not that much productive. Table 3 suggests that not only family expenditure has gone up but also the quality of life and hence expenses for education and luxury have gone up.

Table 7. Annual household expenditure

	Pre-Irrigation	**Post-Irrigation**
Total Family Expenditure in Rs.	109517.2	163058.6
% Expenditure on Food	32.3	29
% Expenditure on Health	10.1	9.4
% Expenditure on Education	7.3	14.8
% Expenditure on Luxury	18.5	22.3
% Savings in Banks, etc.	0.3	0.4

Further socio-economic-evaluation was made in 2020 and similar results were obtained.

6. Application of similar solution in other problematic areas

Command area of the SSP in Becharaji Taluka of North Gujarat region had similar type of problem i.e. sodic soil. From experiences of Bharuch district, similar solution methodology was adopted and the same type of results have been obtained. In total, over 3,50,000 hectare of sodic soil of different parts of Gujarat state of India is being irrigated at present and the productivity is being monitored.

7. Conclusion

Food security has been the utmost priority for the world today for which sustainable agricultural practices and productive use of available soils of whatever type are the most important aspects. Right quantity of irrigation water and selection of cropping pattern are the key to ensure sustainable use of problematic soils. Properly managed irrigation can really be very useful in attainment of the food security and sustainability goals.

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