BENEFITS OF SUPPLEMENTARY IRRIGATION: CASE STUDY OF SARDAR SAROVAR PROJECT OF GUJARAT, INDIA

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ABSTRACT

Planning of irrigation project requires studies like soil health sustainability and drainage feasibility. Some types of soils are not suitable for full irrigation for productive purpose. In case such soils are left to rain fed irrigation, their productivity may not be fully utilized. If such soils are provided supplementary irrigation instead of full irrigation, they might be properly utilized and they might contribute towards attainment of food security. Sustainable irrigation and agricultural practices in such areas are more desirable than keeping them rain fed. India is not only a water stressed country but is also facing soil quality related challenges at large and hence it possesses a great potential to bring a larger area in to equations of irrigation by constructing irrigation projects with supplementary irrigation as a basic philosophy. The paper outlines the overall scenario of India and in its context the situation of Gujarat state. India's accomplishment in food production is commendable but proper use of all available land resources for agriculture is yet awaited. Several irrigation projects with full irrigation philosophy have been built up and have been serving since long back. Contrary to them, Sardar Sarovar Project of Gujarat has been made for providing supplementary or protective irrigation water and its entire command area of 1.8 million hectares includes problematic soils. The paper underlines the fact that a large-scale project designed for supplementary irrigation yields promising results in connection with food security and sustainability, both by making best use of available land and water resources.

Key Words : *Food security, Full irrigation, Soil productivity, Supplementary irrigation, Sustainability*

1. Irrigation in India: past and present strategies

The planned development of irrigation sector started in a big way since the First Five Year Plan (1951-56). Several new projects were taken up during subsequent three plans. During the Fourth Five Year Plan emphasis was shifted to the completion of ongoing schemes. The widening gap between potential creation and utilization was felt in the Fifth Plan (1974-78) and accordingly the Command Area Development (CAD) programme was launched. The Annual Plans 1978-80 and the Sixth Plan witnessed new starts and then the focus was shifted towards completion of irrigation projects. By the end of the Eighth Plan (1996-97), central assistance was provided under Accelerated Irrigation Benefit Programme to help the State Governments in early completion of the projects.

As a result of initiative of Government of India during 1950 to 1970, India developed a large irrigation potential. The gross irrigated area in the country went to 139.9 million hectares (MH) by 2017. This was due to large storage potential of 200 billion Cubic Meter (BCM) created by 1980. Even after achieving the ultimate irrigation potential of 139.89 MH and considering the average irrigation intensity of 140%, the ultimate irrigated area in the country would be only 70% of the net sown area.

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Initial efforts were to create the irrigation potential. Then came the stage of utilising the irrigation potential created. But in all the efforts the focus remained on food security by irrigating maximum possible area under cultivation. Table-1 shows the land use details of India which suggests clearly that out of 328.83 MH land, the net area sown is approximately 142 MH out of which only 58 MH is sown more than once a year. Net irrigated area is 68.38 MH and irrigation potential created is little more than 100 MH. 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 mostly resorting to productive irrigation by bringing maximum possible arable land under reliable irrigation and by increasing the crop yield.

Table 1. Land Use Details of India (MH)

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

Review of accomplishments of the hitherto efforts suggests some amendments needed to be introduced in order to ensure sustainability in the agricultural sector. The limitations crept in to the initial efforts that needed urgent attention included gap between irrigation potential created and utilised, improper cropping pattern from soil suitability point of view, unsustainable irrigation methods and practices, large area excluded from agriculture due to soil characteristics, etc.

The gap between irrigation potential created and utilised was attempted to be bridged up by implementing the CAD Programme and a headway could be attained by 2006. Cropping pattern not suitable to the soil characteristic being largely attributable to the market could not be effectively addressed and has been a serious issue till date. Commendable efforts have been made by the Government of India and various state governments to introduce sustainable irrigation methods and various initiatives under the Prime Minister Krishi Sinchai Yojana (PMKSY). Micro irrigation is the prime initiative at present. Strategies to utilise area excluded from irrigation mainly consist of supplementary irrigation and selective cropping considering the soil characteristics. All the said activities are certainly to be within the limits of the water availability. Besides all of them being duly executed, overdependence on groundwater has been a huge threat for India. Climate change induced extreme events have posed another threat before the water managers.

2. Role of irrigation in attainment of food security in India

Since independence (from the 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 initial 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 millions 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 2. 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 3. 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

Table 4. 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

In production of food grains, 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.

3. Food security: next step for India

Steep rise food grain production is though commendable, the same came not be maintained for infinite time as resources required for that i.e. land and water are limited. In order to maintain food security, India needs to bring in to equations more land which is considered so far as difficult-to-cultivate and at the same point of time to enhance the water use efficiency.

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 and then identifying suitable soils for agriculture and to transfer water resources to those locations. Constraint is the locations of water resources that would govern the planning. This strategy should be to optimize the benefits from the available land and water resources within given natural constraints. In both the scenarios – full irrigation and supplementary 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 more feasible to provide some little water there rather than selecting the best quality soil for brining under full irrigation. Productive or full irrigation where water resources are sufficient and soils are good and protective or supplementary irrigation elsewhere would be the right proposition.

4. Gujarat: a water stressed western coastal state of India

Gujarat is divided in to four regions - South Gujarat which also includes Central Gujarat, North Gujarat, Saurashtra and Kachchh. South Gujarat is water rich and is also having clayey soil, North Gujarat is water stressed and having alluvial soil, Saurashtra is facing shortage of water and is having a mix of black cotton soil with gravels whereas Kachchh is having sandy soil and a large area of desert. Coastal length of Gujarat is the highest in India which is 1664 Kilometres.

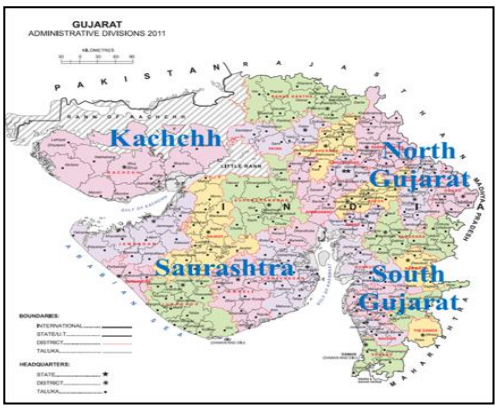

Figure 1. Regions of Gujarat

Except South and Central Gujarat there has been scanty water in the entire state. If compared the per capita water availability, it is much less than India's average and from 2001 onwards there is a significant reduction therein which has caused a serious

concern. This is because of population growth, development of industries and climate change.

Table 5. Surface water scenario of Gujarat

Region	Area in % of Geographical Area of Gujarat State	Surface Water in Mm^3	Ground Water in Mm^3	Total Water in Mm^3 and Percentage	Per Capita Per Annum Availability in m^3 in 2011 and (2001)
South and Central Gujarat	25	31750	3950	35700 (71 %)	1695 (1880)
Saurashtra	33	3600	4300	7900 (16 %)	487 (540)
North Gujarat	20	2100	3300	5400 (11 %)	309 (343)
Kachchh	22	650	450	1100 (2 %)	658 (730)
Total	**100**	**38100**	**12000**	**50100 (100 %)**	**893 (990)**

There are many small and non-perennial river basins coupled with low yields due to scanty rainfall in Saurashtra and Kachchh. In South and Central Gujarat, a few but big and perennial river basins are there.

Table 6. Rainfall Distribution of Gujarat

Name of Region	Annual Rainfall in mm	No. of River Basins
North, Central and South Gujarat	800 to 2000	17
Saurashtra	400 to 800	71
Kachchh	Less than 400	97

Water scarcity and lopsided distribution of water resources are the main issues. Climate change related occurrences are increasingly being reported which can be learnt from average number of rainy days and average number of dry days on annual basis. It is also reported that there is a significant increase in number of heavy rainfall days and of dry days in two-third of Gujarat. In a nut shell, Gujarat has a large arid area of 62,180 km^2 which is 31.72% of its geographical area and a larger semi-arid area of 90,520 km^2 which is 46.18% of its total geographical area. Frequency of deficit rainfall i.e. less than 75% of average rainfall is once in three years.

5. Sardar Sarovar Project of Gujarat: planning for supplementary irrigation

The 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 water distribution in irrigation command and to address a large encompassment of 9600 villages and 135 towns for supply of domestic

water. Planning of command area of the SSP has been made considering many constraints. It has been designed with protective or supplementary irrigation approach. Its irrigation plan was developed by early 1970s. Average annual delta designed in the command area was decided as 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.

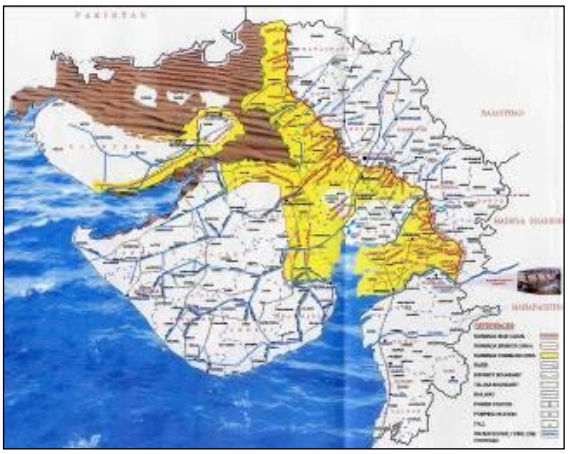

Figure 3. Sardar Sarovar Project, its canals system and command area

The SSP is a multipurpose project on Narmada River whose water is shared by four states – Madhya Pradesh, Maharashtra, Gujarat and Rajasthan. Share of Gujarat out of 28 Million Acre Feet (MAF) of water availability at 75% dependability is 9 Million Acre Feet (MAF) which was used as the basis of water use planning.

It was known at the planning stage itself that the command area of the SSP was heterogeneous in respect of agronomic features and levels of socio-economic development. Rainfall variations and topographic characteristics were also found varying across the command. Therefore, the entire command area could not be taken as a single unit for agricultural and irrigation planning. The command area was divided in to regions considering the ultimate objective of (a) choosing feasible sets of crops for each region, (b) regional allocation of water and its efficient management and (c) planning for conjunctive use of canal and ground water taking in to account the regional potentials and constraints. A region was considered as the unit for crop planning and derivation of parameters for irrigation capacities and capabilities. Following factors were considered for regionalization of the command area.

(i) annual rainfall
(ii) land irritability class including drainage characteristics
(iii) ground water quantity and quality in terms of ground water table and salinity of water in the upper aquifers
(iv) alignment and the command of major branch canals

Thus, the command area was divided in to 13 homogenous regions taking in to consideration annual rainfall, land topography, soils, ground water quality and depth and drainage conditions.

Table 6. Rainfall Distribution of Gujarat

Mean Annual Rainfall in mm	**Region No.**
800-1000	1,2
700-800	3,4,5,6

600-700	7,8,9,10
400-600	11,12,13

From average rainfall it was known that almost three fourths of the command was drought prone areas.

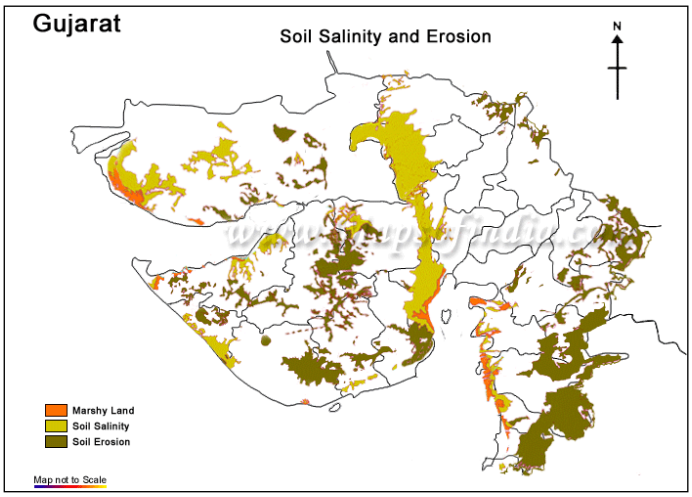

Figure 4. Soil salinity and erosion map of Gujarat

Table 7. 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

Soils in Gujarat were envisaged to be of 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. Canal network of the SSP traverses several problematic soil stretches besides saline soils. Another problem with the state is of sea water intrusion as it has 1664 Km long sea coast. Groundwater extraction in want of surface water aggravates the same. The saline areas are increasing with passage of time. Existing irrigation projects are also affected due to this issue.

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 SSP, 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 was attempted to be achieved.

Drainage condition also found varying across the command area. There were four drainage zones in which the command area was classified and as per drainage complexity level they were enumerated. Drainage Zone-IV means the most problematic one from drainage point of view. As per the design philosophy, it was envisaged that 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, irrigation and drainage were envisaged to work in synchronicity.

Special irrigation plans were been prepared for special regions like Bhal and Bara Tract.

Crop plans were designed on three considerations. First, basic agronomic features would limit the possibilities of choices available in each region. Second, the farmer would make his choice on the basis of the available technologies and their development, the economic opportunities available to him through the development of markets and relative prices and the amount and timing of the water available. Systems were developed to understand his responses to likely developments in each aspect. Third, the crop planning problem then was to take full cognizance of his responses, but to determine water application in each region taking in to account the need to maximize the return of water, subject to the cost if the system, giving explicit consideration to social objectives like removal of regional disparities in income and employment generation within command.

Net irrigation requirements for the crops were worked out on the basis of modified Penman's method. Fifty percent dependable fortnightly rainfall was used in the analysis. The overall irrigation water use efficiency was considered at 60 percent. Region wise fortnightly water demands for chosen crop sets were worked out and used to arrive at peak water demands.

Conjunctive use of surface and ground water was envisaged with a stipulation that a larger part of ground water would be used directly without passing through the distribution system. Thus, overall irrigation water use efficiency would be the weighted average of efficiencies in canal and ground water use.

Detailed and careful consideration was made in the SSP to all the factors responsible for sustainable irrigation. Specific features of the plan which were to improve the efficiency were –

(i) controlled delivery of water
(ii) charging for water on volumetric basis
(iii) maintaining an induced scarcity of water
(iv) lining of canals
(v) on and off operation of lower distribution system
(vi) discouraging perennial and summer irrigation through canal waters
(vii) intensified command area development programme for on-farm development
(viii) intensified extension services for educating the farmers in better irrigation practices
(ix) improved communication systems and automatic control of regulating devices
(x) training of irrigation management personnel

A comprehensive supplementary irrigation plan was prepared and implemented in the SSP. The project has been almost completed and the benefits have started being availed.

6. Benefits in special areas

Bhal and Bara Tract being challenged parts of the command area, they were taken special care of from irrigation and drainage planning point of view. The canal irrigation was started in Bara Tract in 2004 but the canals could not sustain for a long due to clayey soil with high swelling pressure resulting in to breakage of lining and unevenness of the bed slope. Restoration with proper technology was done in 2010 and 2011 and the command area started giving encouraging results. Sustainability of irrigation was a matter of concern and therefore study on response of soil was continuously going on in this area.

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 which concluded that irrigation in the Bara Tract was sustainable.

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.

(i) 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. Cotton and pulses have been the main crops and they have improved significantly after irrigation. Some new varieties of pulses have also been sown.

(ii) Animal husbandry has been an allied activity with agriculture which 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.

Table 8. Annual income from livestock (Indian Rupees)

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

(iii) 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. Not only family expenditure has gone up but also the quality of life and hence expenses for education and luxury have gone up.

Table 9. 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.

7. Benefits in arid and semi-arid regions

The command area of the SSP largely comprises of arid and semi-arid areas. A base line socio-economic study was carried out in Banaskantha district which remained the most challenging part of Gujarat for a long before it received the canal waters. It suggested a grim situation due to dessert like soil and no water resources. The study captured initial trends when the canal system had just began supplying water which suggested fast improvement in the crop yield and drinking water situation.

Considering the fact that the real impact of irrigation can be ascertained after a decade or longer from the time of commissioning of the canal systems, an exclusive study was made in 2019 to assess the impact of the SSP on 10 arid and semi-arid districts of Gujarat. The regions where the project has been implemented were considered as treatment regions and other regions were considered as control regions. Summary of findings are following.

(i) Average cultivated land is higher in treatment villages as compared to control villages. The average irrigated land has also increased in both Kharif and Rabi seasons after development of the command. The number of crops cultivated in treatment villages have also been greater than the control villages. The crop yield and average profit has increased in treatment villages as compared to control villages for many crops. With the increase in gross cultivated area and cultivation of a greater number of crops, agricultural costs increased by 15.10%, while agricultural incomes increased by 37%. Therefore, there was a net increase in agricultural incomes.
(ii) Availability of fodder has also increased. Income from livestock has also increased. The wage rate has also increased in all the arid and semi-arid districts. Expenditure of households in treatment villages has increased than the households in control villages. This implies better economic condition of households residing in treatment villages.
(iii) There has been a positive impact of the SSP on availability of safe drinking water supply. There has been a significant shift in drinking water sources from groundwater to water supplied by the SSP. In-house tap is the primary source of

drinking water for 87% households in treatment villages, and for 83% households in control villages. The shift in the source of drinking water has direct impact on health conditions.

(iv) In terms of educational parameters, the treatment villages showed better performance than the control villages in terms of literacy and years of schooling. It has been found that agricultural (labour) work has increased in treatment villages. Some diversification into dairying could be observed especially by women due to availability of fodder in treatment villages. What is majorly noticeable is the overwhelming proportion of female members (52.01%) pursuing dairying as a secondary occupation in treatment villages. The impact of the SSP on women's empowerment is at best mixed with men retaining the edge on most indicators.

(v) The average profitability has been found higher for the marginal, small and semi-medium cultivators of the treatment villages as compared to the cultivators with same land size in control villages. The SSP has been especially helpful to the marginal, small and medium cultivators as compared to cultivators with large size land.

The results of the study have indicated that through the operations of the SSP the irrigation related constraints have been sufficiently reduced to promote household welfare germane to agricultural activities.

8. Overall impact of the SSP and Conclusion

(i) The SSP fulfils the domestic water requirement of Gujarat to the extent of 80%.

(ii) Energy saving of around 1350 MW due to reduced groundwater extraction in the command area has been a bonus in addition to the hydropower generation of 1 billion units per year with the installed capacity of 1450 MW. Saving in electricity and hydropower generation has significantly reduced the carbon footprint, coal consumption and water footprint.

(iii) Owing to the command area development of the SSP, agricultural production has witnessed a phenomenal rise. The average yield of cotton has been steadily increasing from a mere 130 kg/ha in 1949-50 to 624 kg/ha in 2006-07 which has been reported 1080kg/ha in 2020-21. In the same period, the yield of wheat has been increased from 300 kg/ ha to 2100 kg/ ha in 2010-11 which has been reported 3204.77 kg/ha in 2020-21. Rise in yield has been reported in almost all the crops. The total agricultural production has also gone up along with the yield. The agricultural production was about 10.5 million tons in 1990-91 whereas it increased significantly as high as to 25.3 million tons in 2010-11 which has been reported 46.573 million tons in 2020-21.

(iv) Gujarat with 5.5% of share in area of India, 6% of population and 2.5% of water resources has contributed 8.12% to India's GDP in 2020-21 which mainly because of the role of the SSP.

(v) Food security has been the utmost priority for the world today. Sustainable agricultural practices and 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.

(vi) There are always doubts and debates in the case of such massive development and agriculture related investments, specifically related to

distribution of welfare effects among the deprived class of households. Results suggest that the SSP has been able to reduce the socio-economic differences in relation to size of agricultural operations and incomes besides contributing to Gujarat's food production and economic development in a sustainable manner.

(vii) Sustaining food security of India is practically feasible by replicating best practices adopted in the SSP to make best use of available water and land. Supplementary irrigation can really help a lot in attainment of food security for India especially when brining all available soils including difficult-to-cultivate has become necessary.

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