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Micro Irrigation in Gujarat – Its Need, Potentiality and Status

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Gujarat state is situated in the western part of India. It is surrounded by Arabian sea in the West, state of Rajasthan in the North - East, international boundary with Pakistan on the North, Madhya Pradesh in the East and Maharashtra in the South - East and South. It has the longest sea coast in India with a length of about 1600 km. It is located between 20^0 01' and 24^0 07' North latitudes and 68^0 04' and 74^0 04' East longitudes. It covers an area of 19.6 M ha (1.958 lakhs km^2) contributing to 6 per cent of the total geographical area (TGA) of the country. The state had 19 districts earlier, which subsequently has been divided in to 26.

The population of the state according to 2011 Census is 6.03 crores accounting nearly 5% (4.99%) of the country. The density of population is 308 persons/km^2 and it is lower than all India figures of 382 persons/km^2. The rural population is 57 per cent of the total while 43 per cent lives in urban area.

The climate of the state exhibits a wide variability ranging from arid in the Kutch and adjoining northern and North-West portions of Saurashtra and North-West part of North Gujarat. In the Valsad, The Dangs and Navsari districts situated in the down South of the state, it is sub humid, while the rest of the state enjoy the semi arid climate.

The mean annual rainfall varies from 300 mm (Kutch) and 2800 mm (The Dangs) contributing to 15 to 80 per cent of the Potential Evapotranspiration (PET). More than 95 per cent of the rain fall received in the state is through the South-West monsoon which sets in during mid June and extends up to second fortnight of September. The number of rainy days varies from as low as 15 in the Kutch to as high as 90 in the Dangs.

The mean annual temperature of the state range from 26^0 to 28^0 C. The summer maxima varies from 36^0 C in the coastal region to 43^0C in the inland. During the year, the mean monthly minimum temperature is lowest during January and it varies from 10^0C and 14^0C. The coastal belt under the maritime influence shows more equitable temperature throughout the year and the annual values range between 5^0C and 8^0 C.

In general the winds are weak over Gujarat except during the monsoon months especially in the coastal belt of Saurashtra and in the Panchmahals with a mean velocity of 15 kmph. In the South-western part of Kutch also the wind velocity is comparatively high with a figure of 12 kmph. Over rest of the state, the wind velocity is moderate and Vadodara experiences the minimum wind velocity with the annual average wind speed of 5 kmph.

The per capita availability of water at the state level as per the 2001 census has been reported to be 1121 m^3 per year. Falkenmark, suggested 1700 m^3 per person as the critical level for assessing the sufficiency of per capita availability. If we go by this standard, then the state is in the shortage category. Among the different regions, in North Gujarat, the per capita availability is less than 500 m^3.

Status of surface and ground water potentials in the state

Surface water

Gujarat is endowed with many rivers some of which are perennial while many are seasonal. The perennial large rivers like Narmada, Tapi, Mahi and small ones like Daman Ganga *etc.*, are flowing in the South and middle Gujarat. On the other hand in North Gujarat, the rivers are not only very few but also seasonal in flow. Sabarmati, Banas, Rupen and Saraswati are the important ones.

The total surface water potential of the state is 38.5 thousands MCM of which 32.3 thousands MCM is contributed by South and central Gujarat (Table 1). The contribution from North Gujarat is only of the order of 2 thousand MCM. As against this, the ground water potential is only 16 thousands MCM. Though, the combined contribution of South and central Gujarat is the maximum yet unlike the surface water potential wherein the contribution from this region is 84 per cent, in ground water potential the contribution is only 35 per cent. Thus, out of the total water potential of 54.5 thousands MCM about 38 thousands MCM is contributed by the South and central Gujarat working out to a percentage of 70. The corresponding percentages for North Gujarat, Saurashtra and Kutch are 6.1, 9.2 and 1.2.

Table 1: Surface and ground water potentials of Gujarat ('000 MCM)

Region	Surface water	Ground water	Total
South and central	32.3	5.7	38.0 (69.7)
North Gujarat	2.0	4.1	6.1 (11.2)
Saurashtra	3.6	5.6	9.2 (16.9)
Kutch	0.6	0.6	1.2 (2.2)
Total	**38.5**	**16.0**	**54.5**

( ) = % of total water *Source:* Anon. (2000)

The water requirement form agriculture, which was 93 during 2000, will be going down steadily and it will contribute to 80 per cent of the total water requirement by 2025. This reduction is mainly due to the more percentage demand by other sectors and not due to reduction in the quantity of water required in this sector. In fact by 2025 the state needs 16 thousand MCM more of water for agriculture.

Ground Water

Development

During 1997, out of the 16000 MCM of ground water recharge at the state level, it was estimated that about 13000 MCM was estimated to be utilizable recharge. About 9700 MCM was estimated to be the draft leaving around 3100 MCM as ground water balance. The level of ground water development was 76 per cent, and the state was categorized as grey. But, at the districts levels there are wide

variations ranging from white to over exploited categories .Out of the 5 North Gujarat districts, three, namely Mehsana, Gandhinagar and Banaskantha are falling under over exploited category while Ahemedabad and Sabarkantha are no better with the percentages development of 93 and 89, respectively. On the other hand, the utilization of ground water in the southern districts was very poor. In Surat district, which has got the maximum balance of ground water with a figure of 756 MCM/year is utilizing only 32 per cent of the same.

There has been a steady increase in the ground water exploitation over the years. While during 1984, all districts were falling under "white " category, three districts during 1997 were falling under over exploited category, one under dark and six under grey leaving only nine districts under white category. Out of the 184 talukas, during 1984, 163 talukas were falling under white category which got reduced to 96 talukas during 1997. Simultaneously, the talukas under over exploited category during 1984 were only 5 and which increased to 31 during 1997.

Quality

The ground water quality in the state is subjected to three major constituents. They are mainly salt concentration, nitrate and fluoride. From the salt concentration point of view, the waters of the eastern belt districts from Dangs to Sabarkantha are generally good while salinity/ sodicity is observed in the waters of coastal belt of Gujarat and Saurashtra regions including Kutch and in the inland areas adjoining the coastal tract. The nitrate problem is encountered more in the districts of Amreli and Bhavanagar of Saurashtra region and the North Gujarat region experiences to the maximum of fluoride problem.

Irrigation

Out of the 124 lakh hectares of culturable area, the gross irrigated area in the state was 38.4 lakh hectares working out to a percentage of 31. The corresponding net irrigated area was 30.8 lakh hectares with a percentage of 24.8.

The area under gross canal irrigated area with a hectarage of 7 lakhs contributes to 18 per cent of the gross irrigated area in the state leaving around 82 per cent as ground water irrigated area. The tank command in the state is less than 1 per cent. In general, quality of aquifers is deteriorating except in the eastern portion of South Gujarat. Salinity ingress is the main problem in coastal belt. Except in Dangs, in all other districts of the state, fluoride content in the ground water in toxic levels has been reported. TDS and nitrate contents are also on the rise.

Need of micro irrigation in Gujarat

The erratic and insufficient rainfall, depleting ground water resources especially in North Gujarat and Kutch, water logging and secondary salinization development in South and middle Gujarat coupled with poor irrigation efficiency envisages the need of a better water use efficient method of irrigation in the state. Micro irrigation (MI) is one of the answers to mitigate the above said problems. Further, there are many other factors which favour MI adoption in the state as outlined below.

Factors favouring microirrigation technology in gujarat

- ✓ Predominant arid and semi arid conditions
- ✓ Water scarcity situations in major parts of the state
- ✓ Rapid development of horticulture since last decade
- ✓ Longest coast line, resulting in soil and water salinity conditions demanding micro irrigation for proper management
- ✓ Hilly and undulating terrain on the eastern border
- ✓ Dominance of drip responsive non food grain crops over food grains
- ✓ Marginally saline water in many parts of the state which if used in traditional method of irrigation will affect soil health adversly
- ✓ Poor irrigabilty nature of the soil in many places
- ✓ Presence of number of micro irrigation manufacturers/dealers in the state

Potentiality of micro irrigation in the state

Total potentiality

Considering the source-wise irrigated crops for the micro irrigation feasible crops in different districts of the state, Raman (2007) estimated a potentiality of 3.8 million hectares in the state. Considering that in 30 per cent of the cases, the same system can be used in a cropping system, the potentiality has been fixed at 25.6 or 26 lakhs hectares. There have been changes in the cropping pattern in the state since the last MI potential estimation which was made based on the area under agricultural (2005-06) and horticultural (2006-07) crops. Subsequently, he reassessed the potentiality based on the available statistics for agricultural (2008-09) and horticultural (2009-10) crops. The assessment indicated a potentiality of 4.09 million hectares as per the 2011 estimation as against 3.80 million hectares (Fig.1) of 2007 estimation registering about 7.5 per cent increase. Considering that in about 30 per cent of the cases the system can be used for another crop the estimated areas for 2010 and 2011 are 2.7 and 2.9 million hectares, respectively.

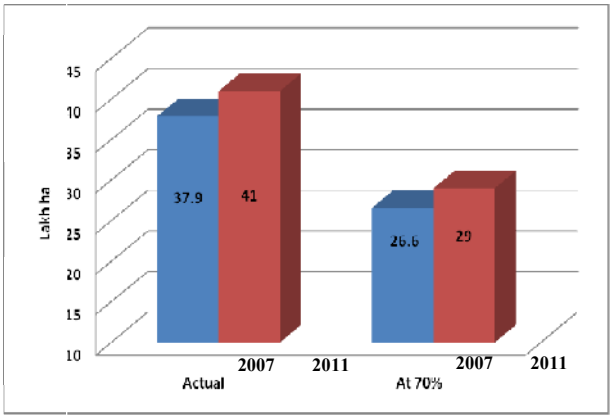


Fig. 1: Micro irrigation potential in the state

Crop groupwise potentiality

Out of the 4.09 million hectares of estimated potential, the contribution of agricultural crops is as high as 3.34 million hectares working out to a percentage of 82 (Fig. 2). The remaining 0.72 million hectares is contributed by 0.14 million

hectares of fruit crops, 0.28 million hectares of vegetable crops and 0.30 million hectares of spices and condiments. The contribution from flower crops is negligible.

The major observations on the contribution of different crops/crop groups in the reassessed potentiality over the 2007 potentiality are given below.

Fig. 2: Crop group-wise potentiality (%) of MI

- In the agricultural sector the estimated potential showed an increase of around 3 lakhs hectares and major increases are in sesamum, castor, wheat, bajra (summer), groundnut (summer) and cotton, while in mustard there is reduction.
- In fruit crops mango, banana and papaya contributed more to the increase which is to the tune of around 17000 hectares.
- In the vegetable, an increase of around 26000 hectares is observed and almost all the major vegetable crops contributed significantly to the increase in the potentiality except onion which showed a decrease due to the year to year fluctuating tendency in the area.
- In the spices and condiments, there has been a reduction in the overall potentiality to an extent of around 49000 hectares. This is mainly due to the reduction in the percentage considered for the potentiality from 80 (2007) to 50 (2011) in cumin. This has been purposely done as we do not have appropriate recommended technology for adoption of MI in this crop though some farmers adopt MI for cumin in the adjoining state of Rajasthan.

Districtwise estimated micro irrigation potentiality

Among the different districts, the potentiality is maximum in Banaskantha (4.5 lakhs) which is followed by Rajkot (3.8 lakhs), Bhavanagar (3.6 lakhs), Junagadh (3.5 lakhs) and Surendranagar (3.1 lakhs). In all other districts, the potentialities were less than 3 lakhs hectares (Table 2).

In the South Gujarat, districts of Valsad, Navsari, Surat, Tapi, Bharuch and Narmada and the middle Gujarat districts of Anand, Panchmahals and Dahod and North Saurashtra district of Porbandar the potentialities were less than 1 lakh hectare. The Banskantha, Rajkot, Junagadh, and Bhavanagar contribute to 44 per cent of the total micro irrigation potentiality in the state (Fig. 3). On the other hand, Narmada, Panchmahals, Valsad, Navsari and Tapi together contribute only 2.8 per cent of the total potentiality.

Table 2: District-wise potentiality (000ha) of MI in Gujarat

Districts	2011	2007	Districts	2011	2007
Ahmedabad	132	113	Anand	77	56
Amreli	250	187	Mehsana	256	208
Banaskantha	447	453	Patan	147	87
Bharuch	62	68	Panchmahal	32	29
Narmada	24	27	Dahod	39	74
Bhavnagar	363	293	Rajkot	382	441
Dang	NE	NE	Sabarkantha	229	241
Gandhinagar	122	93	Surat	51	42
Jamnagar	251	288	Surendranagar	307	229
Junagadh	346	315	Baroda	195	205
Porbandar	40	43	Valsad	20	33
Kutch	166	141	Navsari	18	20
Kheda	119	89	Tapi	21	30

Source : Raman (2011) (Personal communication)

Micro irrigation adoption trend since 2005-06

Approach of the GoG for implementation of the MIS

Till 2005-06, the micro irrigation schemes in the state were implemented by the Director of Agriculture and Director of Horticulture depending upon the crops. Since the MI is one of the many schemes being implemented by the respective

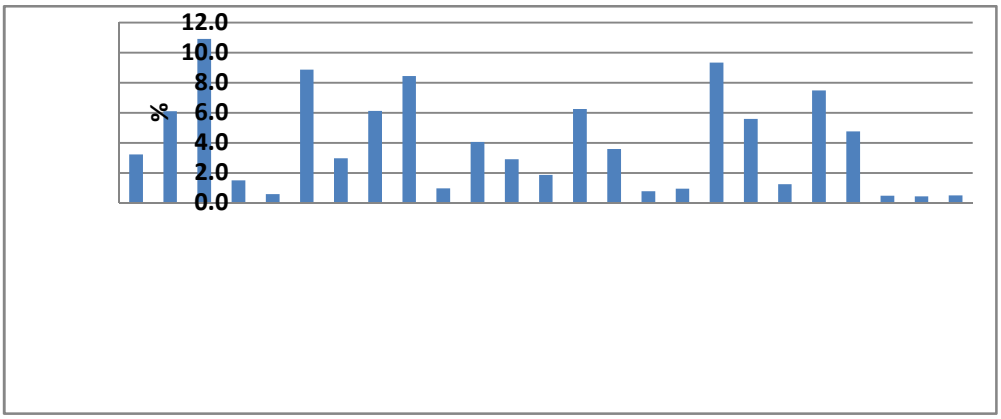


Fig. 3: District wise contribution to the potentiality of MI

directorates, the government wanted to give priority to MI in the state and conceived a single nodal agency with single objective with integration of all MI schemes.

Thus, during May, 2005 the Gujarat Green Revolution Company Limited (GGRC), a Special Purpose Vehicle (SPV) promoted by Gujarat State Fertilizers & Chemicals Limited, Gujarat Narmada Valley Fertilizers Company Limited and Gujarat Agro Industries Corporation Limited, was formed. The government of

Gujarat identified it as the Implementing Agency for all micro irrigation schemes in the state and it is recognized by the Govt. of India for implementing Micro Irrigation System (MIS) in the State of Gujarat.

GGRC Initiatives

The initiatives taken to popularize micro irrigation adoption in the state by GGRC are outlined as below.

- Under the GGRC module of the MI Scheme, all types of Micro Irrigation Systems *i.e.,* drip, sprinkler, mini (impact) sprinkler, micro sprinklers and porous pipes are included and offered to the farmers according to technical suitability and farmers' choice.
- GGRC implements the MIS scheme of Govt. of Gujarat and Govt. of India in uniform subsidy pattern of 50 per cent of the total MIS cost or Rs.60,000/- per hectare whichever is less.
- The unique features of the scheme is hand holding the beneficiary farmer by facilitating bank loan as per need, providing with insurance coverage for the system as well as the beneficiary for a period of 5 years, agronomical services rendered to the farmers for 2 crops season/one year and maintenance of the system by the MIS suppliers.
- GGRC modality of working takes into account the flexibility of price variation of the system components based on price variation of the raw material which has been a regular feature.
- GGRC modality takes into account the inspection of each and every installation site by independent inspection agencies which involves material verification as well as trial-run of the drip irrigation system.
- Incorporation of the work of 'e-Capture Solutions' which will be carried out from mobile camera in different array and spectrum to cater various purposes related to Third Party Inspection along with GPS Co-ordinates.
- GGRC modality takes into account the quality assurance system of the supplied components by the MI companies to the farmers through the inspection and assessment of manufacturing capabilities and MI components by technical agencies CIPET, GERI and GIRDA.
- GGRC has commissioned Agricultural Finance Corporation for concurrent monitoring and evaluation of the micro irrigation scheme at an interval of every two years with one per cent of sample survey.
- For assessment of socio-economic impact of the scheme, reputed NGOs of the state are engaged and they carry out this assessment on yearly basis covering two per cent samples.
- All the State Agricultural Universities are engaged for audit inspections as the third party inspection agencies.
- Involvement of NGOs, Sugar Factories, APMCs & Corporate bodies in promoting MIS concept in tribal areas through MIS partner model.

- Training programmes for Tribal youth in MIS installation and maintenance so as to generate trained manpower.
- Training of Village Level Workers (VLWs) at district level throughout the State.
- Trainers' Training Programme on MIS in collaboration with Navsari Agricultural University, Navsari.
- Execution of MIS in GWRDC tube-well command areas through Pressurized Irrigation Network System (PINS).
- Promotional activity for MIS concept awareness through print and electronic media is a regular feature. Extensive crop based promotional activities are carried out seasonally.
- Advertisement through Hoardings and Bus Back panels, tractor trolley painting, wall painting *etc*., carried out across the state.
- Active participation in agricultural events like '*Krishi Mahotsav'* / Exhibition.
- Sensitization of farmers through publication and distribution of informative brochures, literatures, leaflets, calendars, posters, MIS Portfolios, caps, T shirts *etc*., amongst the farmers.
- Publishing GGRC advertisements and articles in various magazines, periodicals, souvenirs and news papers in order to create awareness about the business module of GGRC.
- Documentation and publication of success stories on micro irrigation.
- Publication of Bi-monthly magazine '*Jal Jivan*' emphasizing on popularization of information and knowledge on water management through micro irrigation.
- To enhance pace and precision of the operations of processing of MIS application and also to have transparency in the implementation process, all operational aspects are made IT enabled.
- Rendering the services of Personalized Professional Information to farmers through mobile phones in vernacular SMS. Information related to weather forecast, mandi rates, agricultural advises *etc.,* is provided to beneficiary farmers.
- The District Administration plays a crucial role in generating demand, monitoring and coordinating the progress at district level through District Micro Irrigation Committee (DMIC). At State level, the programme is steered through State Micro Irrigation Committee (SMIC), presently chaired by the Principal Secretary (Agril. & Cooperation). The State Govt. has also formed a Cabinet sub-committee under the Chairmanship of Hon. Minister of Revenue to oversee the progress of the scheme and take appropriate policy decisions at State Govt. level.

Status of adoption of micro irrigation

The area under micro irrigation between 2005-06 and 2011 -12 was 4.8 lakh ha. Out of 2.6 lakh ha area is under drip and that under sprinklers 2.2 lakh ha. In the

initial 15 years *i.e.,* between 1990 and 2005 the average annual adoption of micro irrigation was 15000 ha amounting to 2.25 lakh ha. However, between 2005 and 2012, the average installation works out to be around 69000 ha annually. In fact, since last couple of years the installations are more than in one lakh ha annually.

***Number of beneficiaries*:** Between 2005-06 and 2011-12, about 2.93 lakh beneficiaries availed subsidy from this scheme for adopting micro irrigation. The numbers of beneficiaries adopting drip were 1.42 lakh as against 1.51 for sprinkler. The year and system wise progress in the beneficiaries is presented in fig. 4.

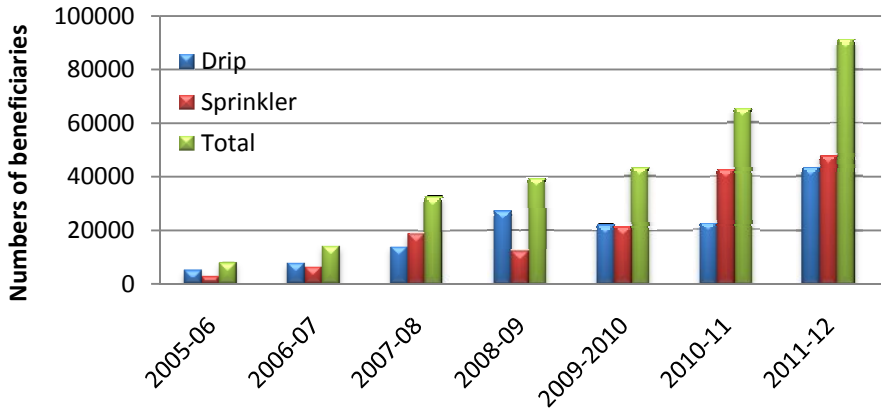
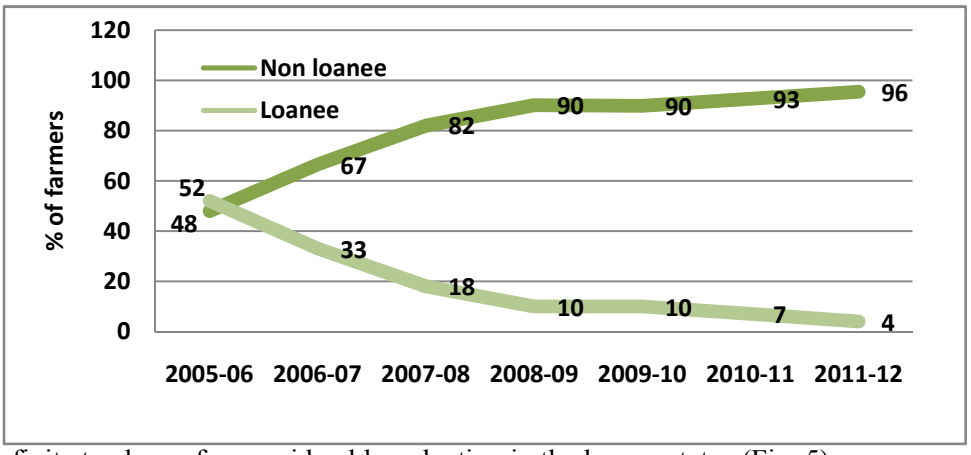


Fig. 4: Year-wise progress of beneficiaries

***Loanee status*:** Out of the 2.93 lakhs beneficiaries, during the 7 years as high as 2.62 lakhs beneficiaries did not opt for loan while only 0.31 lakh beneficiaries availed the loan facility. The year-wise trend indicates that over the years there is a



definite tendency for considerable reduction in the loanee status (Fig. 5).

Fig. 5: Trend in loanee status

During 2005-06 the loanee status (52 %) was more than that of non loanee. But it got regularly reduced and came down to as low as 4 per cent during 2011-12. This is an encouraging trend, as one of the reasons for the reduction in the loanee status, may be that the farmers might have got confidence that they can recover the money they have invested on micro irrigation system in reasonably good period.

***System-wise micro irrigation adoption trend*:** During the last seven years about 4.75 lakh ha were brought under micro irrigation in the state. The area under drip was 2.45 lakh ha and it was 2.30 lakh ha under sprinkler. Though, it may appear that the adoption of both the systems contributed to almost same extent, yet in the initial years drip adoption was considerably more than that of sprinkler (Fig. 6). But, during 2010-11 and 2011-12 the sprinkler adoption was considerably more than that of drip. Though, this may be due to more adoption of micro irrigation in tribal areas mainly with sprinklers, yet the trend needs to be reverted back as drip and mini sprinklers are more efficient systems than sprinkler.

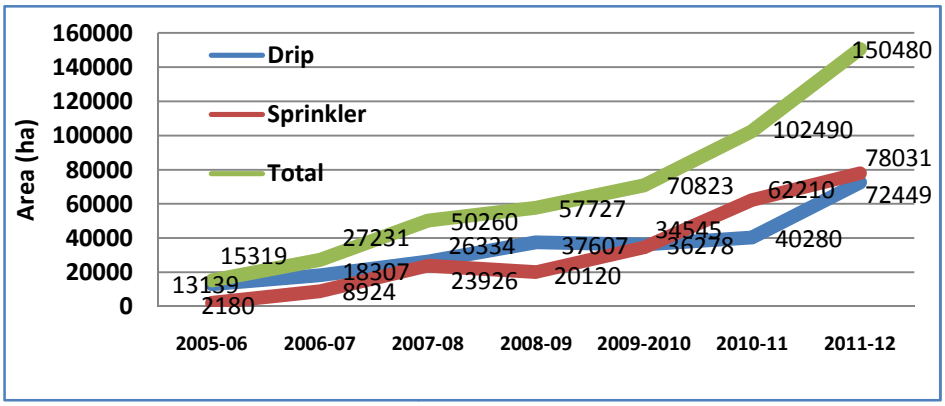


Fig. 6: Systemwise micro irrigation adoption trend

***Crop group wise micro irrigation adoption*:** During2005-06 and 2010-11 around, 3.24 lakh have come under micro irrigation. Out of this around 67000 ha were under horticultural crops and the remaining under agricultural crops. Thus, between the agriculture and horticulture crops the per cent adoption was considerably more in agricultural crops (Fig. 7).

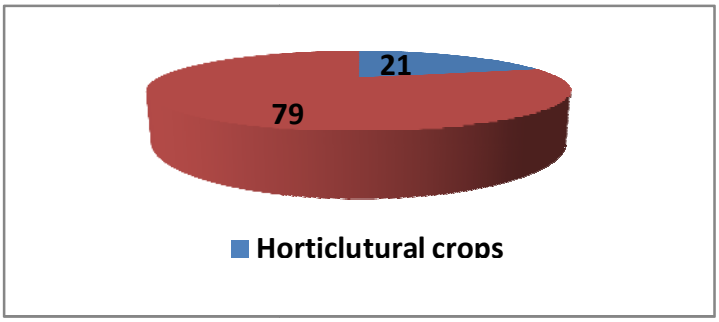


Fig. 7: Crop group-wise adoption of micro irrigation

Crop-wise adoption : Among the different crops, groundnut alone contributed to about 42 per cent of the adoption followed by cotton with nearing 26 per cent (Fig.8).

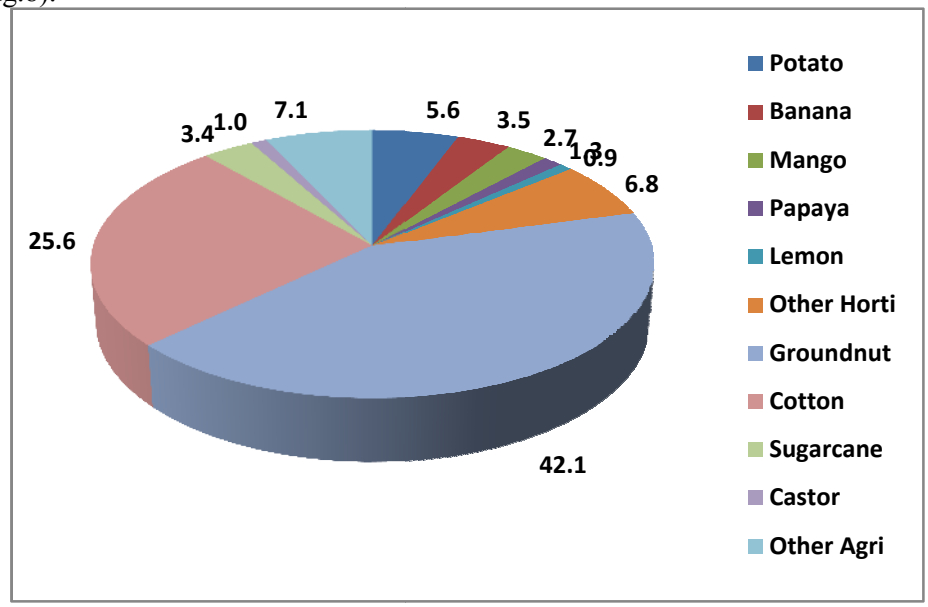


Fig. 8: Crop-wise distribution (%) of MI

Thus these two crops combined contributed to 68 per cent of the total micro irrigation adoption during the period under report, while all other crops contributed only 32 per cent. While sprinkler accounted as the micro irrigation system under groundnut, it was drip for cotton. More than 80 per cent of the micro irrigated potato crop was irrigated through minisprinkler.

***District-wise micro irrigation adoption*:** The micro irrigation system adoption is observed in all the 26 districts of the state though to a different extent (Table 3).

Out of the 4.75 lakh ha brought under micro irrigation during these 7 years, as high as 74 thousand ha have been contributed by Banaskantha, followed by Junagadh with 53 thousand ha and Sabarkantha with 49 thousands ha. In fact these three districts together contribute to nearly 37 per cent of the micro irrigation adoption in the state (Fig. 9). The contribution in each of the districts of Anand, Dangs, Gandhinagar and Patan are less than one per cent.

Table 3: Area under micro irrigation in different districts between 2005-06 and 2011-12

District	Area (ha)	District	Area (ha)
Ahmedabad	7042	Mehsana	5416
Amreli	26505	Narmada	9257
Anand	2328	Navsari	9435
Banaskantha	73845	Panchmahal	8726
Bharuch	11147	Patan	4150
Bhavnagar	28672	Porbandar	11042

Dahod	10231	Rajkot	29340
Dangs	2082	Sabarkantha	49323
Gandhinagar	3796	Surat	12849
Jamnagar	21545	Surendranagar	19187
Junagadh	53330	Tapi	11722
Kheda	5344	Vadodara	30049
Kutch	19334	Valsad	9209

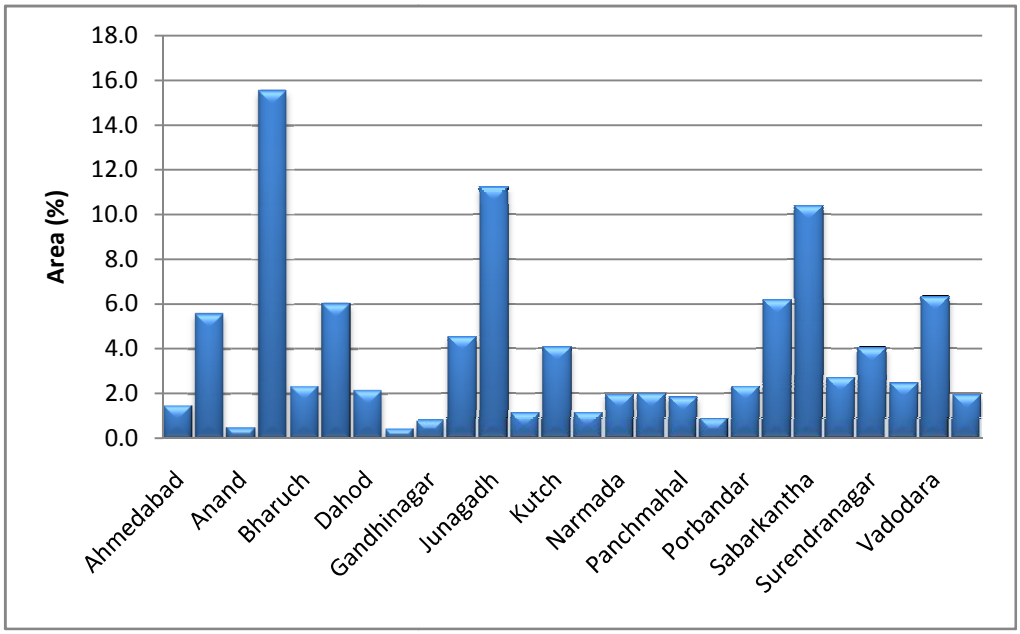


Fig. 9: Districtwise contribution to micro irrigation area

Proposed new initiatives for increasing area coverage

In addition to continuation of the approaches made during the 11th five year plan including the intensification of Partner Model and Cluster Approach, PINS in government tubewells, following additional initiatives will be taken during the 12th FYP.

MIS in SSP Command

In the Sardar Sarovar Project, the water is very scarce and the water availability to the farmers will be of the order of only 33cm per hectare in most of the command except in *Bhal* and *Bara* tracts where it is going to be only 25 cm. With this very low water availability, only through MIS the farmers can successfully grow two crops in a year and in *Bhal* and *Bara* tracts for growing even one crop successfully there is a need for MIS. Secondly, out of the 13 irrigation zones of SSP, only two zones are fit for normal irrigation. In rest of the zones either the soil or

ground water quality or both restrict the normal irrigation practice to be followed. A high power committee has already recommended that in *Bhal* and *Bara* tracts, no surface or gravity fed irrigation should be done and it should be only lifted from a farm pond.

Further, with the introduction of MIS, the feasible irrigated area in the command can be nearly doubled. Adoption of MIS in the VSAs in the SSP area can assure water availability to each farmer and equity in distribution and tail end problems can be resolved. Successful adoption of MIS in a canal command area can be done only if a sustainable Pressurized Irrigation Network System (PINS) is created which is techno economically viable. In SSP command, where the process of construction of sub minors and field channels are still in progress, adoption of PINS can reduce to a great extent the problems of land acquisition and save the cost involved in creating the network through the conventional distributory system. Already some pilot studies are in progress in this aspect in SSNL command.

MIS in the Tail- end of Ukai-Kakrapar and Mahi-Kadana Commands

Though the Ukai-Kakrapar and Mahi-Kadana commands are perennial, the tail end problem is acute forcing many farmers to go in for well irrigation with saline water. There is possibility of storing canal water in these tail- end areas either in the village or farm ponds from which the farmers can irrigate the crop by lift and MIS.

MIS in non command areas of canal command

With in the canal command area, where canal water can not be reach by gravity due to landform constraints, the farmers are lifting canal water for irrigation, in such areas there is a good scope of MIS provided electrical connection are allotted on priority basis.

Integrating MIS with watershed development programmes

There are many watershed development programmes run in the state funded by different sources including state, central government, NABARD *etc*. In all these projects where the farm ponds or check dams are involved use of MIS should be made compulsory.

Use of MIS in protected cultivation and mulching

Of late, there is spurt of adoption of green house and net house cultivations in the state. The government of India has separately earmarked subsidy pattern for installation of micro irrigation for these activities. Further, the area under mulching is also increasing considerably in the state. Mulching and micro irrigation has got a lot of synergistic effect which can be exploited.

MIS in NHM and NHB activities

There are many NHM and NHB activities like area expansion, nursery management *etc.*, funded through the central government. Micro irrigation should be made obligatory in all these activities.

Conclusions

The state of Gujarat is water scarcity one and there is an imminent need and lot of scope for adopting micro irrigation. In fact, it with the potentiality of nearly 3 million ha for MI, it is the fourth most potential one and only UP, Rajasthan and MP are ahead of Gujarat. This state has become a unique one by establishing the Gujarat Green Revolution Company with complete autonomy and empowering it to be the nodal agency for implementing all the state and central schemes in unified and integrated way. This has reflected in the steep rise in the adoption rate of MI from around 15000 ha per year prior to establishment of GGRC to around 69000 ha per year between 20005-06 and 2011-12 (Post GGRC establishment period). In fact, presently Gujarat contributes to nearly 10 per cent of the total MI installations in the country.

During these 7 years, 4.8 lakh ha have been brought under MI benefitting around 2.93 lakhs farmers. Agricultural crops contribute to around 82 per cent of the installations comprising of groundnut with sprinkler and cotton with drip are the most predominant crops. The modality of working and various activities taken up by the GGRC in enhancing the MI adoption by the state alongwith the new initiatives to be taken up in the next 5 years are outlined in the paper.

In short, the vision of the government in establishing GGRC as an independent organization for implementing the MI schemes may be one of the important reasons for the state getting figured as one of the leading MI adopting states in India.

The successful functioning of GGRC may be mainly attributed to its COMPLETE TRANSPARENCY at all stages of implementation right from application to final payment especially THROUGH WELL DEVELOPED ONLINE SYSTEM coupled with good monitoring system and training to different stakeholders in collaboration with different institutes/organizations.

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Water Management Research in North Gujarat and Kachchha

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Indian agriculture dates back to the ear of Harappan civilization. Our national economy is predominantly agrarian and land holding have always been the most sought after possessions. However, land holding subsequently shirked through generations. Thus, land holding of majority of our present day farmers' are of either small or marginal category and have to be tuned to face grim realities of commercial farming. To gain from the promising opportunities made available through globalization and free market enterprise, one of the most important strategies is to use the available water resources in most efficient way so as to turn market driven agriculture to farmers' advantage.

Physiography and rivers

The North and North-West agroclimatic zones of Gujarat consisting of Banaskantha, Sabarkantha, Mehsana, Patan, Gandhinagar and Kachchh districts lies between 22^0 44' N to 24^0 7' N latitude and 68^0 4' E to 73^0 8' E longitude. Physiographycally, the whole area is delineated in to three units *viz.,* border high lands, mid plains and western plains. The border high lands have an altitude ranging between 300 and 1090 m mainly comprising of the talukas of Danta, Khedbrahma, Vijaynagar and Bhiloda. These are at the foothills, which are the continuation of the major outline chairs like Sahyadris in the South. The river Sabarmati rises in the South-West, spurs of the Aravalli hills near Vakariya and traverses through Sabarkantha. The river Sabarmati has a length of over 300 km with an extensive catchment area. The river Rupen rises from the Tungo mountains flows through Sabarkantha and Mehsana districts and extincts in to the Little Rann of Kachchh. The Saraswati river flows through Sidhpur, Patan, Harij, Palanpur, Dantiwada, Deesa and Kankrej talukas of Banaskantha district and Radhanpur talukas of Patan district. The North plain is an uninterrupted plain sloping gently from North-West to South-West which includes Vav, Tharad, Deodar, Radhanpur, Santalpur, Harij and Sami talukas.

The crescent shaped region called Kachchh, forms part of North-West zone. Inspite of being treeless, barren and rocky, the physical features of Kachchh are characterized by ranges of hills and isolated peaks, rugged and deeply cut river beds, well tilled valleys and tracts of rich pasture land. On the South, besides a high bank of sand, the sea coast lays a low fertile and well- cultivated plain. Beyond this plain, the region is interrupted by three hill ranges *viz.,* Kachchh proper, Vagad in the East and the Rann elevation in the North.

The hills of Kachchh are properly spread widely in the West that become narrow towards the East and contain one noticeable peak, Dhinodhar about 387 m above MSL reputed to have been a legendry volcano. The backbone of Kachchh proper is the "Chaduva" range of hills running from West ward Anjar and continue upto the Garda hills in the neighbourhood of Lakhpat. The hilly elevation of the Rann contain the peak point of elevation of Pachham(458 m MSL), Khadir (860.5 m MSL) and Bela (68.58 m MSL). South of Pachham, is an extensive low line track known as *Banni*, the mystery land of Kachchh, running almost parallel to the Rann of Kachchh for 104.6 km. The entire expanse of Rann of Kachchh and Little Rann of Kachchh situated on the northern and eastern sides, respectively is covered with a thick salt layer mixed with fine sand and clay, devoid of vegetation and habitation.

All the rivers and streams of Kachchh start from its central portion and flow towards the sea in the South-West and the Great Rann in the North and Little Rann in the South-East. Kachchh rivers are ephemeral. Among the North flowing rivers are the Bhurad, the Kali, the Godhated, the Suvi, the Dhudud, the Malan, the Chang, the Nara, the Khari, the Rav and the Kalia. The South flowing rivers include the Rukmavati, the Naghali, the Lakadiavali, the Bhukhi, the Sang, the Sai and the Rakhdi.

The area of *Banni* lies on the northern side of main lands of Kachchh. *Banni* is a grassland area of 1,312 km^2 having 45 villages where in families of *maldharies* live. It is a part of Rann and highly salt-affected, deposition of alluvium by river improved vegetation. The salinity / sodicity varies widely. About 30 different grass species have been identified.

Climate

Annual normal rainfall of various districts of North and North-West Gujarat varies between 353 mm and 807 mm with coefficient of variation ranging from 37 to 52 per cent. The distribution of rainfall, measured in number of rainy days indicates that it is as low as 15 days in Kachchh and as many as 35 days in Sabarkantha district. The arid areas with low rainfall (less than 500 mm) covers entire Kachchh, western halves of Patan and Banaskantha while Mehsana, Gandhinagar and Sabarkantha districts come under the semi-arid climate where normal annual rainfall ranges between 500 to 1000 mm.

In general, winter is very cool and dry whereas, summer is extremely hot. May is the hottest month while January is the coolest, June to September represent the monsoon season. The mean monthly minimum temperature ranges between 9.5^0C and 27^0C, while mean monthly maximum temperature ranges between 26^0C and 42^0C. The mean annual temperature ranges between 25^0C and 28^0C. During summer intense solar radiation and high wind velocity causes dust storms, resulting in wind erosion of top soil that adversely affects soil fertility and crop cultivation particularly in Kuchchh and northern tips of Banaskantha.

The mean monthly relative humidity varies from 65 to 90 per cent at 7.30 hrs and 20 to 65 per cent at 14.30 hrs. The mean annual relative humidity varies from 50 to 60 per cent. The relative humidity in the arid region is lower compared to other semi-arid regions, indicating unfavourable circulation of the atmosphere and low

precipitation. Mean relative humidity is generally high during June to September (60 to 80 %).

The potential evapotranspiration values of all locations were found to vary between 1614 mm to 1998 mm. The highest atmospheric demand was observed in the entire Kachchh district and Kankrej taluka of Banaskantha. Generally, water deficit were observed during January to May at all the locations. In Kachchh, the water demand has been always higher than rainfall with obvious maximum water deficiency (1429 mm to 1592 mm). Further, the water deficit ranges 1099 mm (Vadgam) to 1358 mm (Kankrej) in Banaskantha.

Soils

A systematic soil resource inventory of Gujarat on 1 : 2,50,000 scale was undertaken by NBSS and LUP. The soil resources map on 1: 5,00,000 scale showing 370 units has also been prepared. Based on this information, 140 units have been identified in the jurisdiction area of North Gujarat and Kachchh region. The physiographic unitwise details of soils are given in table 1. The soils of both the zones are sandy in texture with low water holding capacity. Apart from erosion, salt affected soils are encountered in some pockets of both the zones.

Table 1: Physiographic location wise soil types in North Gujarat and Kachchh region

Agroclimatic zone	Physiographic locations	Predominant sub order association
North Gujarat	Border high lands	Orthents, Ochrepts
	Mid plains	Fluvents, Psamments, Ochrepts, Orthids
	Western plains	Argids, Aquents, Psamments, Usterts(in pockets)
North-west Gujarat (Kachchh)	Eastern plain	Orthents, Aquepts, Psamments, Ochrepts
	Western plain	Orthids, Argids, Psamments

Irrigation

The total surface water potential of the state in 38.5 thousands MCM of which only 2.0 and 0.6 thousand MCM comes from North Gujarat and Kachchh region. The ground water potential of Gujarat is only 16 thousand MCM, out of which only 4.1 and 0.6 thousand MCM from North Gujarat and Kachchh.

Out of the 54.5 thousand MCM/yr of available water, 19.1 thousand MCM is being utilized in Gujarat. In North Gujarat, where the availability is 6.1 thousand MCM/yr and the utilization is 6.0 thousand MCM (98 %). In other words, all the available waters are almost utilized in this region. The utilization in Kachchh is 58 per cent.

Source wise irrigated area

In both the zones (North Gujarat and Kachchh region), the major source of irrigation water is ground water (93 %) and the remaining 7 per cent is covered by surface water. Among the districts, Banaskantha and Mehsana are having about 5 per cent area irrigated through tube wells and that in Banaskantha and Sabarkantha about 88 per cent area is irrigated by dug / other wells. This is also true for Kachchh (Table 2). Because of this, North Gujarat zone is extremely water scarce and categorized in over exploited zone. This amply reflected in per cent area irrigated through ground water which is 92 and 86 per cent in North Gujarat and Kachchh, respectively, as against the 80 per cent in Gujarat (Fig. 1).

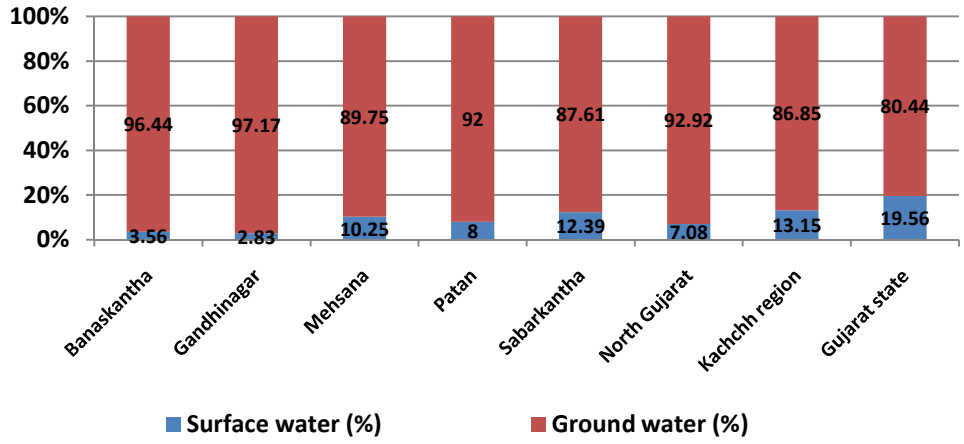

Fig. 1: Source wise net irrigated area in North Gujarat and Kuchchh region

Ground water development

With respect to ground water balance, it is negative in Banaskantha (-91.45 MCM/Yr), Gandhinagar (-41.09 MCM/Yr) and Mehsana (-557.42 MCM/Yr) districts and positive in Sabarkantha (86.54 MCM/Yr) and Kachchh (70.41 MCM/Yr). However, at region level it is negative (-533.01 MCM/Yr). This is also substantiated by the ground water development of 164.5 per cent in Mehsana and 146.04 per cent in Gandhinagar which ultimately classified as over exploited districts. Though, the ground water balance in Sabarkantha and Kutchchh is positive, yet it is on the border where in the ground water development is around 88 per cent (Table 3).

Land use

The land use pattern in North Gujarat and North- West Gujarat zones is rather different than that of the Gujarat as a whole. In North Gujarat, the net cultivated area is around 70 per cent as against only 14 per cent in North-West zone (Kachchh). Similar variation is also evident in culturable waste and barren/ uncultivated land which is around 36 per cent each in Kachchh and only about 3-4 per cent each in North Gujarat (Fig.2).

Table 2: Source wise irrigated area in different districts of North Gujarat and Kachchh (Year 2006-07)

(Area '00 Ha)

Sr.No.	Districts	Tanks		Canals		Tube wells		Other (Dug) well		Other sources		Total area irrigated	
		Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross
1	Banaskantha	19	18	130	135	2516	3245	1517	1772	6	6	4188	5176
2	Gandhinagar	6	6	25	35	888	1183	169	189	6	6	1094	1419
3	Mehsana	18	18	206	211	1747	2289	206	206	9	9	2186	2733
4	Patan	6	6	97	103	850	1017	72	78	262	331	1287	1535
5	Sabarkantha	7	7	256	276	499	730	1339	1831	21	21	2122	2865
North Gujarat		56	55	714	760	6500	8464	3303	4076	304	373	10877	13728
									09	4	4	1642	2092
		42							**02**	**1016**	**1166**	**42376**	**52787**

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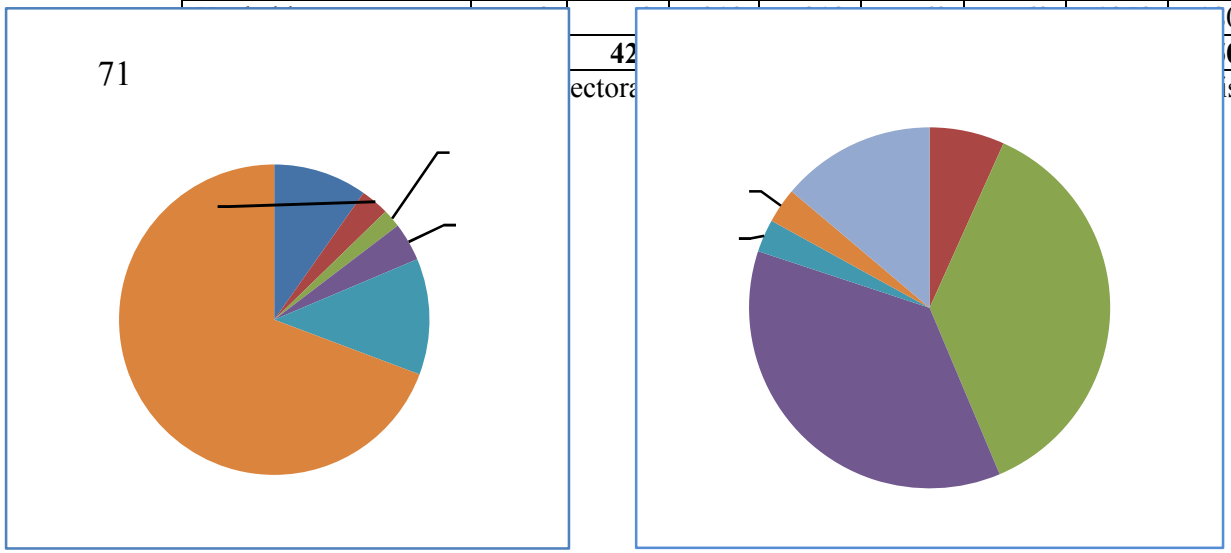

Fig. 2: Land use classification of a) North Gujarat and b) Kachchh zone

Table 3: Ground water potential, recharge and draft of North Gujarat and Kachchh (Year- 1997)

Sr. No.	Name of Districts	Total recharge (MCM/Yr)	Utilizable recharge (MCM/Yr)	Gross draft (MCM/Yr)	Balance (MCM/Yr)	Development (%)	Category
1	Banaskantha	994.80	795.84	887.29	-91.45	111.49	OE
2	Gandhinagar	111.57	89.26	130.35	-41.09	146.04	OE
3	Mehsana	1077.78	862.22	1419.64	-557.42	164.65	OE
4	Sabarkantha	961.83	769.46	682.92	86.54	88.75	Grey
5	Kachchh	627.00	501.60	431.19	70.41	85.96	Grey
Total		3772.98	3018.38	3551.39	-533.01		
North Gujarat (Average GW development) :127.73							
Kuchchh region (Average GW development): 85.96							

OE= Over-exploited

Crop and cropping pattern

The majority area of the North Gujarat and North-West agroclimatic zones are climatically categorized in to arid zone. Apart from aridity, sandy soils, severe water scarcity, low rainfall, excessive ground water development (> 100 %) *etc.* are the major crop production constraints. Under such harsh agroclimatic conditions, there is not much diversity in the crops and cropping pattern (Table 4). During *kharif* season, in both the zones irrespective of districts, pearl millet, castor, cluster bean and cotton are the major crops. Similarly, during *rabi* season, wheat is the major crop along with mustard and some spices like fennel, cumin *etc.,* in some districts are cultivated predominantly. Inspite harsh agroclimatic conditions, the productivity of pearl millet in Gandhinagar and Mehsana, sorghum in Banaskantha, castor in Banaskantha and Gandhinagar, clusterbean in Mehsana and Patan and fennel (*rabi)* in Banaskantha is much higher than the state level productivity (Tables 5 & 6).

Table 4: Major crops in North and North- West region of Gujarat

District	Season		
	Kharif	***Rabi***	***Summer***
Banaskantha	Pearl millet, Cluster bean, Castor, Green gram, Sesamum, Cotton, Moth bean, Sorghum, Maize	Mustard, Wheat, Cumin, Isabgol	Pearl millet
Sabarkantha	Maize, Tur, Castor, Groundnut, Cotton, Green gram, Urd, Rice, Cluster bean, sesamum, Pearl millet	Wheat, Fennel	Pearl millet, Groundnut
Patan	Maize, Tur, Castor, Groundnut, Cotton, Green gram, Urd, Rice, Cluster bean, sesamum, Pearl millet	Wheat, Fennel	Pearl millet, Groundnut
Mehsana	Pearl millet, Cotton, Castor, Cotton, Green gram, Cluster bean, Sesamum, Urd, Rice	Wheat, Mustard, Cumin, Fennel	Pearl millet
Gandhinagar	Castor, Rice, Pearl millet, Cotton, Cluster bean, Sorghum, Green gram, Sesamum	Wheat, Mustard	Pearl millet
Kachchh	Cluster bean, Pearl millet, Groundnut, green gram, Castor, Cotton, Sesamum, Moth bean	Wheat	Groundnut

Table 5 : Area and yield of *kharif* season crops of North Gujarat and Kachchh region (Mean of three years-2007-08,2008-09 & 2009-10)

Area in '00 ha, Yield in kg/ha

No.	District	Pearl millet		Sorghum		Castor		Cluster bean	
		Area	Yield	Area	Yield	Area	Yield	Area	Yield
1	Banaskantha	1439	543	106	2058	781	2254	619	422
2	Gandhinagar	134	1268	5	1285	259	2181	32	418
3	Mehsana	429	1215	6	1277	488	2077	79	646
4	Patan	700	550	0	0	401	1521	102	645
5	Sabarkantha	52	663	932	1316	487	1701	67	416
6	Kachchh	646	1041	0	0	551	1690	665	485
7	**Gujarat**	**5852**	**1036**	**4182**	**1261**	**4045**	**1971**	**1596**	**368**

Table 6 : Area and yield of *rabi* season crops of North Gujarat and Kachchh region (Mean of three years-2007-08, 2008-09 & 2009-10)

Area in '00 ha, Yield in kg/ha

District	Wheat		Mustard		Cumin		Fennel		Isabgul	
	Area	Yield	Area	Yield	Area	Yield	Area	Yield	Area	Yield
Banaskantha	681	2616	1461	1464	273	568	21	1756	84	551
Gandhinagar	352	2951	75	1495	2	554	7	1358	0	0
Mehsana	670	2801	466	1416	128	472	59	1662	20	472
Patan	294	2723	484	1425	208	464	17	1565	3	456
Sabarkantha	1046	2362	107	1393	21	521	38	1332	1	564
Kachchh	252	2794	108	1552	103	569	0	0	58	647
Gujarat	**10811**	**2708**	**2823**	**1448**	**2397**	**543**	**187**	**1539**	**178**	**579**

Water Management Technologies

North Gujarat and Kuchchha are most water scares regions in Gujarat. As described earlier in both the zones, are characterized by extremely sandy soils, low and erratic rainfall, negative water balance *etc*. Because of all these adversities, commendable work related to water management envisaging surface, drip and sprinkler methods of irrigation has been done. Further, in some of these technologies developed are also including mulching and fertigation techniques for different crops. The irrigation method wise technologies developed are briefly described here.

Surface irrigation technologies

In all 14 technologies of surface irrigation method were developed by covering about 6-7 important crops like castor, mustard, wheat, fennel, fenugreek *etc.,* Among different crops, castor (*rabi*) being long duration crop requires bout 14 irrigation at 10 days interval during October and November and at 15 days interval during December to February (Table 7). The next in order is fennel which requires 10 irrigations under Jagudan (Mehsana) conditions. Rest of the crops requires irrigation between 3 to pigeon and 7 to wheat and other crops. The variation within the crop is

due to either location or variety (long or short duration). Under water scarce condition for crop like fennel water saving could be achieved through adopting alternate furrow irrigation by reducing the depth of irrigation but keeping the number of irrigation same (7).

Table 7: Surface irrigation technologies for some crops of North Gujarat

SN	Crop (Variety)	Location	No. irri. (D: mm)	Schedule	Year/ JA. No.
1	Amaranthus (GA-1)	S.K. Nagar	6 (50)	AS, 5-6 DAS, rest 20 DI	1996/25
2	Castor (GAUCH-1)	S K Nagar	5-8	15 days after cessation of monsoon 20 DI	1996/25
3	Castor (GAUCH-1 or GCH-4)	S.K.Nagar	8 (50)	15 DI Sept. - Nov., 20 DI Dec. - Feb.	1996/25
4	Castor (R)	SKNagar	14 (60)	10 DI Oct.-Nov., 15 DI Dec.-Feb.	1998/27
5	Chickpea	S.K. Nagar	5	20 DI	1995/24
6	Fennel (G-11)	Ladol	7(60) 7(40)	1st -18-20 DI,2nd & 3rd -13 DI, 4th & 5th - 15 DI, 6th & 7th- -14 DI Water scarce condition (Alternate furrow)	2010/6
7	Fennel (GF-1)	Jagudan	10 (50)	AS, 8, 33 DAS, Rest 12-15 DI	1998/27
8	Fenugreek	S.K. Nagar	7	AS, Rest 15 DI	1992/21
9	Green gram (Su)	SKNagar	7 (60)	First 3 at 9 DI, Rest 7 DI	1997/ 16
10	Mustard	SKNagar	5 (50)	PS, 15, 45, 60, 70 DAS,	1998/27
11	Pigeonpea (BDN-2)	S.K.Nagar	3 (60)	15-17 DI after cessation of monsoon	1996/25
12	Wheat	Vijapur	7 (60)	21, 34, 45, 56, 67, 78, 91 DI	1989/18
13	Wheat (Lok-1)	Vijapur	7 (60)	AS,15 DAS, rest 12 DI	1993/ 22
14	Wheat (GW-173)	Vijapur	5 (50)	PS, 18, 35 DAS, rest 10-12 DI	1997/26

AS: At the time of sowing, DI: Irrigation interval in days, D: Depth (mm), DAS: Days after sowing

Drip technologies

The schedule of drip method of irrigation for 17 different crops covering 4 field crops, 6 fruit crops and 7 vegetable crops has been developed and recommended to the farmers of North Gujarat and Kuchchha (Table 8). Among the field crops, maximum water saving of 51 per cent was achieved in fennel and that of minimum of 26 per cent was recorded in cotton crop in comparison to conventional method of irrigation. Not only this, but an increase yield was ranging from 9 per cent in fennel to as high as 49 per cent in Bt cotton over surface method of irrigation. In the cases of fruit crops, the water saving was found to vary between 12 percent in ber and 69 per cent in custard apple compared to surface method of irrigation. Irrespective of fruit crops, the yield increase with drip irrigation method was around 20 per cent over surface method of irrigation. With respect to vegetable crops, the water saving was ranging from as low as 8 percent in brinjal to as high as 45 per cent in okra (summer). Similarly, an increase in yield of vegetable crops, due to drip irrigation was varying between 12 per cent in potato and 43 per cent in tomato as compared to surface method of irrigation. In order to achieve fertilizer saving, fertigation was attempted in crops like guava, potato, cabbage *etc.* Due to adoption of fertigation, the saving of N could be achieved upto 40 percent. Along with water saving, fertilizer saving and yield increase under drip method of irrigation, net return per mm of water used was also computed. The net return per mm of water used was maximum of 109 Rs./mm with *ber* and that of minimum of 25 Rs./mm was with castor crop.

Table 8 : Drip irrigation technologies for some crops of North Gujarat (Agroclimatic zone IV)

SN	Crop (Spacing, m)	System details	Operating System	Remarks
1	Gauva/ L-49 (6 X 6)	0.7 PEF Drip system Lateral spacing:600 cm Dripper spacing : 600 cm Fertigation study-60%RDN	Monthly interval -60% RDN in four equal split each in May, June, September and October.	- Higher yield - 53 % water saving - 32 % higher fruit yield - Saving 40% N
2	Pomegranate / Ganesh (6 x 6)	0.70 PEF Drip system Lateral spacing:600 cm Dripper spacing : 600 cm Dripper discharge : 8 (No.2)	330 min. Oct-Jan. 420 min. Feb.-March	- Higher yield - 49% water saving
3	Ber / Gola (6.5 x 6.5)	Lateral spacing:650 cm Dripper spacing : 50-100 cm Dripper discharge : 4 (No.10)	60-105 min.	- 17% Higher yield - 12% water saving - 109 NR/mm
4	Mango (Var.Rajapuri) (8 x 8)	0.6 ADFPE Drip system Lateral spacing:800 cm Dripper spacing : 30-60 cm Dripper discharge : 8 (No.2-5)	Vary with age and no. of dripper	- 9% Higher fruit yield - 21 % water saving

Table 8: Continue…

SN	Crop (Spacing, m)	System details	Operating System	Remarks
5	Aonla (Guj. Aonla-1)	0.4 PEF Drip system	Vary with age and no. of dripper	- 20 % higher yield - 31% water saving
6	Custard apple (var. Sindhan)	0.4 PEF Drip system	Vary with age and no. of dripper	- Higher fruit yield - 69% water saving
7	Fennel GF-1 (0.5x0.5 x 1.0)	Lateral spacing:150 cm Dripper spacing : 120 cm Dripper discharge : 4	90 min.,-Oct.-Dec. 120 min.-Jan-Feb.	- 9 % higher seed yield - 51% water saving - 41 NR/mm
8	Groundnut/ GG-2 (Micro tube)	Lateral spacing: 60cm Dripper spacing : 50 cm Dripper discharge : MT	Under extreme water scarcity, 65 min.-Feb.-Mar. 90 min. April-May	-32% water saving
9	Castor (GCH-4) (0.9 x 0.6 cm)	Lateral spacing:90cm Dripper spacing : 60 cm Dripper discharge : 4	40 min.-Sept.-Nov. 30 min.-Dec.-Feb.	- 36% higher yield -25% water saving - 25 NR/mm
10	Castor (GCH-4) (0.6x0.6 x1.2)	Lateral spacing: 180cm Dripper spacing : 60 cm Dripper discharge : 8	40 min.-Sept.-Nov. 30 min.-Dec.-Feb.	-21 % higher yield
11	Castor (GCH-4) (0.45x0.6x1.35)	1.2 ADFPE through drip + No Black plastic mulch Lateral spacing:180cm Dripper spacing : 60 cm Dripper discharge : 8	125 min. -Oct., 150 min.-.Nov and Feb., 80 min.-Dec.-Jan., 60 min.-March, 200 min.-till harvest	- 9% higher yield -46.4 NR/mm
12	Cauliflower / Early snow	Lateral spacing: 90cm Dripper spacing : 50 cm Dripper discharge : 4	40 min.-Nov.-Jan. 50 min.- till harvest	-43 % water saving -43 NR/mm
13	Cotton (G.Cot.Hy-10)	0.6 PEF with paired row planting method (0.45 x 0.60 x 1.8 m)	-	-23% higher yield -40% water saving
14	Bt cotton	1.0 PEF + 150 % RDF	--	-49% higher yield - 2% water saving -higher net profit with BCR 1 : 3.7

Table 8: Continue…

SN	Crop (Spacing, m)	System details	Operating System	Remarks
15	Summer Okra (cv. Parbhani Kranti)	Lateral spacing: 90cm Dripper spacing : 60 cm Dripper discharge : 4	70 min.- Feb.-March 86 min.-April-May	- 45 % water saving - Higher yield
16	Summer Tomato (Guj.Tomato-1)	0.8 ADFPE	--	- 43% higher fruit yield -26 % water saving
17	Cabbage	1.0 ADFPE with 80% RDN	--	-30% higher yield -20 % N saving -27 % water saving
18	Potato/Khufri Badshah (30 x 60)	Lateral spacing:90 cm Dripper spacing : 50 cm Dripper discharge : 8	25-30 min.- Nov.-Feb. 35-40 min.- March-onwards 240 kg N/ha in 4 equal split)	-12 %Higher yield
19	Potato/ Khufri Badshah (0.45x0.15) (Fertigation)	Lateral spacing:45 cm Dripper spacing : 50 cm Dripper discharge : 4	45 min.- Dec.-Jan. 68 min.- Feb.-March	-13 %Higher yield
20	Potato/ Khufri Badshah (0.6 x 1.2)	Lateral spacing:120 cm Dripper spacing : 60 cm Dripper discharge : 4	40 % N saving	-22% higher yield -40 % N saving -20 % water saving
21	Potato/ Khufri Badshah (0.6)	Lateral spacing:60 cm Dripper spacing : 60 cm Dripper discharge : 4	45 min.- Dec.-Jan. 68 min.- Feb.-March	-26 % higher yield - 44 %water saving -63 NR/mm
22	Chilli	1.0 ADFPE	80 % RDF	- Higher yield
23	Summer Brinjal (cv. BSR-1) (0.5 x 0.75 x1)	0.8 PEF Lateral spacing:150 cm Dripper spacing : 75 cm Dripper discharge : 4	180 min. –Sept-Oct. 140. min.- Nov-Feb. 220 min. –till harvest	-19 % higher yield - 8 % water saving - 50.2 NR/mm

Note : DD: Dripper discharge in lph, (Nos.): Numbers of dripper, NR/ mm: Net return/ha-mm water used.

General instruction for drip technologies:

1) The system should be operated on alternate day at 1.25 kg/cm^2 pressure, 2) Filter unit should be cleaned regularly 3) System should be flushed thoroughly after each event of fertigation and 4) System should be checked frequently for leakage.

Sprinkler technology

Apart from drip method, sprinkler and mini sprinkler methods of irrigation were also tested in crops like groundnut, potato, fenugreek, gram, lucerne, wheat *etc.* (Table 9). Here also, the water saving of the order of 46 per cent was achieved in potato and it was minimum of 11 per cent in gram crop. The yield increase with sprinkler method over conventional method of irrigation was ranging from 4 per cent with potato to 35 per cent with fenugreek under sprinkler method of irrigation over surface method of irrigation. Similarly, net return per mm of water used was maximum with potato (57 Rs./mm) and that of minimum with lucerne (17 Rs./mm). Under North Gujarat condition, irrigation schedule of sprinkler method for wheat was recommended for two situation *viz.,* ample and limited availability.

Table 9: Sprinkler / Minisprinkler technologies for some crops of North Gujarat

S N	Crop / Variety	Location	% WS	% YI	B:C/ NR/ mm	D (mm)	Schedule	Y/ AGR No.
1	Fenugreek Local	Jagudan	29	35	29	40	7 DI: Dec.- Jan. 15 DI: Feb.,11 DI: March	88-90/28
2	Gram	S.K. Nagar	11	31	34	50	12-14 DI	NA
3	Groundnut (S)	S.K. Nagar	23	14	34	40	10 DI	91-93/29
4	Lucerne A-2	S.K. Nagar	28	8	17	40	First 10 irri.: 10 -12 DI, Rest at 5-6 DI	94-95/32
5	Potato/ Kufri Badshah	Deesa	46	4	47	40	I: AS, II: 8 DAS 12-14 DI: Feb.,8 DI: March	89-91/28
6	Wheat	Vijapur	31	18	26	40	Ample water: 15 DI: up to Feb., 10 DI: Feb. –March Water constraints: 21 DI up to Feb., 10 DI: Feb. –March	89-92/29
7	Groundnut (S)/GG2 (30)	S.K. Nagar	18	21	27	20	First 10 irrigation at 5-6 DI, rest at 4-5 DI, Sprinkler spacing: 3 x 3 m	94-95/31
8	Potato/ Khufri Badshah (30)	SK Nagar	35	17	57	12	at 8 DI, Sprinkler spacing: 3 x 3 m	95-97/34

Note: Sprinkler spacing: 1200 x 1200 cm, Operating pressure: 2.75 kg/cm^2

B:C : Benefit : Cost ratio
NR/ mm : Net return per mm of water used
YI : % Yield increase
WS : % Water saving
D : Depth of irrigation (mm)

Note: Mini sprinkler operating pressure: 1.5 to 1.75 kg/cm^2 , operating time depends upon discharge of minisprinkler, DI= Days interval

In order to assess the impact of pressurized methods of irrigation particularly in potato a major crop of Banaskantha district, a special survey was carried out in potato growing areas of Deesa taluka of Banaskantha district which is about 800 ha area was covered under drip and sprinkler method of irrigation. The data pertaining to yield and monetary advantages realized due to drip and sprinkler method of irrigation are given in table 10. Apart from yield advantage of 34 per cent with sprinkler over conventional method of irrigation, farmers opined that there is considerable water saving (up to 50 %), improvement in quality of potato (44%) *etc.* Though potato growers have expressed satisfaction with sprinkler method irrigation in potato crop, yet there is still scope to realize the full benefits of sprinkler through adoption of scientific schedule recommended for potato.

Table 10: Average (n=43) yield of potato under MIS on large scale in Deesa (Dist. BK)

Sr.No.	Parameters	Drip	Sprinkler	Control
1	Average yield (t/ha)	31 (6)	39 (36)	29 (0)
2	Average net profit ('000 Rs/ha)	52	96	51
3	Average water depth (mm/ day)	8 to 9	7 to 8	12 to 15

( ) % increase over control, n= number of farmers

Mulching technologies

Mulching technology was standardized for ber, brinjal and castor crop (Table 11). In ber under rainfed condition, mulching with black plastic (100 μ) after cessation of monsoon, recorded 25 per cent higher yield and untimely the B : C ratio. While in castor grown under rainfed conditions, mulching with either castor shell could enhance castor seed yield by 47 per cent with B : C ratio of 2.0. Similarly, mulching with mustard straw also increased castor seed yield by 10 per cent over no mulch control.

Table 11: Mulching technologies for some crops of North Gujarat

SN	Crop / Variety	Location	Mulch material	% WS	% YI	Addl. income (000'Rs/ha)	Remark	Y / AGR No.
1	Ber	SKNagar	BP (100 μ)	-	25	1.5	Moisture conservation	NA
2	Brinjal	SKNagar	Castor shell	-	19	3.7		92-94/30
3	Castor	SKNagar	Castor shell @ 15 t/ha	RF	47	2.0	-	93-97/34
4	Castor	SKNagar	Mustard straw	-	10	NA	Rainfed crop	NA

BP: Black plastic, NA: Not applicable, WS: Water saving and YI: Yield increase

7

Water Management Research in Saurashtra Region

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The Gujarat is the extreme western state (21°1'-47.7'N lat and 64° 4'-74.4 E long) of India. The state has an area of 1, 95, 984 km^2 representing 6 per cent area of the country. The state comprises of 26 districts. The western peninsular regions are known as Saurashtra and Kutch (20°30'-24^o N lat and 69°-72° E long.) which cover about 40 per cent area of the state. Depending upon the climate, topography, soil characteristics and the cropping pattern, the state is divided into 8 agroclimatic zones. Out of these 8 zones, Saurashtra covers 2 agroclimatic zones *viz.,* North Saurashtra (NSAZ) and South Saurashtra agroclimatic zones (SSAZ). The Saurashtra region includes six districts *viz.,* Junagadh, Amreli, Bhavnagar, Rajkot, Jamnagar and Surendranagar, with total geographical area of 51.83 lakh ha and cultivated area of 36.18 lakh ha. Thus this region contributes 26.44 per cent and 51 per cent of geographical and cultivated area of state, respectively. Saurashtra falls under arid to semi arid climatic region (PET 1873 mm) and rainfall is low (761 mm) and erratic (CV 55%). Parts of Jamnagar, Rajkot and Surendranagar districts of Saurashtra are classified as arid and some parts of Amreli, Rajkot and Bhavnagar falls under semi arid climatic region. The rain which occurs in 38 rainy days during 21 June to 21 September is much less than PET and hence negative annual water balance for agricultural point of view. Moreover, drought after every three years is a regular climatic feature. Therefore, ground water is a crucial determinant for livelihood of the people in this region.

The entire area of NSAZ comes predominantly under the dry region. In terms of the standard climate type (tropical climate) *viz.,* arid and the semi-arid climates are spread over influenced area of the districts in the NSAZ. Out of the total area of the zone, 73.40 per cent area fall under arid and semi-arid. The arid zone contributes 22.31 per cent, while the semi-arid zone forms 51.09 per cent of the total area of the zone. The Jamnagar district has arid climate whereas rest of the other districts experiences semi-arid climates. In the case of SSAZ, it has a semi-arid climate.

Soils

As the geographical formation of Saurashtra is of volcanic origin, the soils are generally derived from basaltic rock known as *Deccan* trap. The soils are shallow

to moderately deep. The detailed information regarding soil types and their characteristics is given in table 1.

Table 1: Types and characteristics of soils of Saurashtra

SN	Soil type	Characteristics of the soils
1	Shallow black soil	Depth ranges from few cm to 30 cm Light grey in colour More than 30% stones in soil Mainly sandy clay loam to clay in texture Structure is weak and mainly sub angular blocky
2	Medium black soil	Slight to moderately alkaline Depth varies from 30 to 60 cm or more at few places Calcareous in nature A layer of *murrum* encountered in subsoil layer Moderately sub-angular blocky structure Dark to light grey colour Silty clay loam to clay in texture Dominant exchangeable cation- Ca
3	Coastal alluvial soil	Sandy clay loam to silty clay loam in texture Moderately alkaline, calcareous and highly saline Medium in fertility Deep soils occur in Junagadh, Bhavnagar and Amreli districts.
4	Hilly soils	Not well developed profile due to steep slope and erosion Shallow to moderately deep Poor in fertility Sandy clay loam to clay in texture Neutral to slightly alkaline in reaction
5	Forest soil (mostly found in SSAZ)	Shallow and calcareous in nature Neutral in reaction Rich in organic matter content
6	Shallow soils (mostly found in SSAZ)	Depth varies from few cms to 30 cms Lack of distinguished profile horizonization
7	Deep black (mostly found in SSAZ)	Colour varies from dark brown to very dark greyish brown Depth - 80 cm to few metres High amount of free lime content Sub-angular blocky structure Clay in texture Poor in drainage Moderately to strongly alkaline in reaction

Table 1: Continue…

SN	Soil type	Characteristics of the soils
8	Mixed red and black soil (mostly found in SSAZ)	Reddish brown colour at higher elevation and grayish brown colour at lower elevation Clay loam to clay in texture Stony material content more than 50% Highly calcareous in nature Alkaline in reaction
9	Saline- Alkaline soil (mostly found in NSAZ	Sandy loam to clay Salinity is mainly due to impeded drainage and faulty irrigation methods
10	Residual sandy soils (mostly found in NSAZ)	Shallow in depth Reddish brown in colour Weak granular structure Sandy to loamy sand and sandy clay loam in texture Non calcareous in nature Neutral to alkaline in reaction

SSAZ = South Saurashtra Agro- Climatic Zone
NSAZ= North Saurashtra Agro- Climatic Zone

Irrigation

Water a scare commodity, is key natural resource for agricultural production. In arid and semi-arid regions, where availability of irrigation water posses a serious threat to the sustainability of agricultural production, it is considered as liquid gold. According to an estimate, irrigation contributes 27 per cent in increasing crop production.

Farmers of Saurashtra region are tempted to use more and more irrigation water from the wells to meet the requirements of intensive cropping which is presently followed by the farmers. This has resulted in very heavy withdrawal of ground water, which has not been simultaneously recharged by the rains. Therefore, the ground water is receding at fast rate and there has been ingress of sea water especially in the coastal strip of the Saurashtra region right from Bhavnagar to Navalakhi port. The situation is more severe at Porbandar, Okha Mandal, Jodia and Malia talukas because of peculiar situation existing at these places with respect to topography, climate, soil *etc*.,

As a results of low rainfall and limited irrigation facilities exist in Saurashtra. Saurashtra has less than 20 per cent of irrigated area of the state limitation of irrigation facilities in Saurashtra is a very serious problem for the agricultural production. In such a situation, attempts should be made for efficient use of limited water available for irrigation so that maximum production can be obtained.

The district and source wise irrigated areas given in table 2 clearly indicate that the major source of irrigation water is ground water (98.5%). The sole dependency on ground water for irrigation may be eased with the completion of Sardar Sarivar Project (SSP). It is planned to cover about 3.04, 0.48 and 0.34 lakh ha area under SSP in Surendranagar, Bhavnagar and Rajkot districts of Saurashtra, respectively.

Table 2: Source wise irrigated area in different districts of Saurashtra (2002-03)

Districts	**Irrigated area (Area in '00 ha)**		
	Canal	**Ground water**	**Total**
Junagadh	22	925	947
Amreli	-	1015	1015
Bhavnagar	-	1688	1688
Rajkot	-	1730	1730
Jamnagar	73	760	833
Surendranagar	15	1083	1098
Total	110	7201	7311
Percent contribution	1.5	98.5	

(Source: Directorate of agriculture, Gujarat state, Gandhinagar. Statistical abstract of Gujarat state-2006)

Land use:

Irrespective of the zones, about 64 per cent of the total geographical area is under cultivation and other land uses varies between 5 to 8 per cent (Table 3).

Table 3: Land use pattern

SN	**Particular**	**Area in lakh ha**			**% TGA**
		NSAZ	**SSAZ**	**Total**	
1	Total geographical area	35.0	16.8	51.8	
2	Cultivated area	22.2	11.0	33.2	
3	Total cropped area	25.8	13.1	38.9	64.0
4	Area under forests	1.5	2.1	3.6	6.8
5	Cultivable waste including grazing lands	2.5	2.1	4.5	8.7
6	Current fallows	1.7	0.8	2.5	4.9
7	Barren and uncultivated area	2.5	0.8	3.3	6.4

Cropping pattern

North Saurashtra Agroclimatic zone

The total cropped area of zone is 25.77 lakh ha being a dry farming region, the entire zone is characterised by mono-cropping system. Based on soil, climate,

irrigation and crop season, the cropping patterns in the zone predominantly consists of crops like groundnut, cotton, pearl millet, sorghum, sesamum, green gram, wheat, mustard, cumin, chickpea garlic *etc.* Vegetable crops are also grown in considerable area during *rabi* season under irrigated conditions in the zone.

The major crop sequences followed in SSAZ are groundnut, groundnut-wheat, groundnut-mustard, groundnut-cumin, groundnut- chickpea, pearl millet-mustard, pearl millet- groundnut, pearl millet-green gram. Pearl millet -cumin, pearl millet-mustard, pearl millet-garlic, cotton, cotton- groundnut. cotton- sorghum *etc*. Apart from this, the crop mixture of pearlmillet + pulses, cotton + green gram, cotton + groundnut *etc*., are being followed during *kharif* season.

South Saurashtra Agroclimatic zone

The total cropped area of the zone is 13.11 lakh ha. During *kharif* season under groundnut occupies major area followed crops like pearl millet, cotton, sorghum, sesamum, castor *etc*. Wheat is the dominant crop of the *rabi* season followed by gram and mustard. In some pockets, summer groundnut and green gram are also grown.

The major crop sequences followed in SSAZ are groundnut- groundnut, groundnut-wheat-groundnut, cotton- groundnut, groundnut-cumin, cotton- pearl millet, groundnut-wheat- pearl millet, groundnut-onion-pearl millet *etc*.

The research work related to water management carried out in different crops at various locations in Saurashtra region are summarized here under.

Water management technologies

As stated earlier, Saurashtra occupy about 51 per cent of cultivated area of Gujarat that too with low rainfall and poor irrigation facility. In view of the typical situation, in all 32 irrigation technologies have been developed covering 17 important crops of Saurashtra region. The irrigation management technologies comprise of 19 surface methods of irrigation, 11 drip method of irrigation and 2 sprinkler method of irrigation. Not only irrigation schedules for 17 crops have been developed, but technologies related to use of poor quality water for irrigation, fertigation, mulching with crop residues, application rate of NPK as well as FYM have also been standardized in some of the crops.

Surface irrigation technologies

Groundnut being important crop of the region, in all four surface irrigation technologies have been developed for this crop using life saving irrigation in *kharif* groundnut, soil moisture depletion and climatological approaches for summer groundnut crop (Table 4). Giving one protective irrigation during dry spell of *kharif* season, pod yield of groundnut could be increased by 78 per cent over rainfed groundnut crop. Similarly, scheduling of irrigation based on soil moisture depletion approach showed superiority over climatological approach in terms of yield (40 %). In general, groundnut grown during summer season requires about 12 irrigations each of 50 mm depth. Feasibility of using high saline and sodic water as protective irrigation was also studied. Application of irrigation water having EC up to 7 dS/m

and RSC up to 10 me/l did not change soil properties significantly. This was tested in groundnut(s)-pearl millet (k) sequence in calcareous soil condition. Among the different crop tested, irrigation water requirement of sugarcane was maximum *i.e.,* 46 irrigations under liberal water availability condition and 39 irrigation under limited water availability. Further, by adoption of trash mulching in sugarcane, about 12 irrigations can be saved without any adverse effect on the cane yield of sugarcane.

Table 4: Surface irrigation technologies for Saurashtra region

Crop	**Approach**	**No of irrigation (Depth: mm)**	**Schedule**	**Remarks**
Groundnut (*kharif*)	Life saving	1	One irrigation during dry spell	78 % over rainfed
Groundnut (s)	SMD	At 50 % SMD	At 7-8 days interval	40% YI over 25%SMd
Groundnut (s)	SMD	12	- Between 0-10 DAS-1 - 10-30 DAS-1 - 30-50 DAS-0 - 50-80 DAS- 4 - 80-90 DAS-2 - 90-105 DAS- 3 and - 105-120 DAS- 1	-
Groundnut (s)	CA	12(50)	- First at sowing - Second at 8 DAS - Third and forth at 12 DAS interval and - Remaining at 8-10 days interval	-
Mustard	CA	7(50)	- First at sowing - Second at 6 DAS and - remaining 5 at an interval of 12-15 days	-
Wheat	CA	10(50)	- Pre-sowing - Second 6 DAS - remaining 8 at 8-10 days interval	Depth of irrigation had no effect on yield
Wheat-Maize(F)	CGS	7	- Irrigation at 8 days interval with 60 mm depth + FYM	-
Wheat	CGS	7	- Irrigation at weekly intervals	Confirmation
Pearl millet	CA	10	- First at sowing - Second at 9-10 DAS - Third and fourth at 8 days interval - remaining 5 at 6-7 days interval	-

Table 4: Continue…….

Crop	Approach	No of irrigation (Depth: mm)	Schedule	Remarks
Green gram	CA	7(50)	- At an interval of 7-8 days	-
Gram	CA	5(50)	- First at sowing - second at 10-12 DAS - remaining 3 at 18-20 days interval	-
Isabgul	CA	14(50)	- First at sowing - second at 6 DAS and remaining 12-15 days interval	-
Garlic	CA	14(50)	- First at sowing - second and third at 5 days interval - 4^{th} to 11^{th} at 10-12 days interval and - 12^{th} to 14^{th} at 7-8 days interval	-
Sugarcane	CA	46 ample 34-limited water with trash mulching	- All irrigation at an interval of 8-10 days	-
Coconut	CA	-	- Irrigate at 25 days interval during winter and 20 days interval during summer	-
Ground nut G'nut (s)-brinjal	Poor quality can be used for giving protective irrigation -EC up to 7.0 dS/m and RSC up to 10 me/lit.			

CA: Climatic approach, CGA: Critical growth stage, SMD: Soil moisture depletion

Drip and sprinkler irrigation technologies

In all 13 technologies comprising of 11 drip and 2 sprinkler methods of irrigation has been developed for Saurashtra region. Basically, these technologies covered about 8 crops like groundnut (s), cotton, castor, vegetable *etc*. In some of the studies fertigation and herbigation have also been tested and appropriate schedules have been standardized. Simultaneously, in summer crop of groundnut subsurface placement of lateral was also tested. In groundnut crop under drip irrigation, stress management was also studied and imposing stress at about 40 days after sowing *i.e.,* drip system need not have significant adverse effect on pod yield. This implies that more water saving in summer crop of groundnut can be achieved through not

operating drip system. Irrespective of crops, water saving in the range of 20-30 per cent and yield increase between 20 and 40 per cent could be achieved by using drip method of irrigation as compared to conventional method of irrigation. Drip method of irrigation with mulching was also tried in brinjal crop and results were encouraging (Table5).

Table 5: Drip irrigation technologies for Saurashtra region

Crop	Approach	System detail	Schedule	Remarks
Groundnut (s)	CA	Lateral spacing: 60 cm Dripper spacing: 45 cm Dripper discharge: 4 lph Operating pressure: 1.2 kg/cm^2	Alternate day Jan- March 1hrs April- June 1 hrs 30 minute	21% YI 20% WS 30.5 kg/ha-cm Fertigation: 100% RDF + Weedicides
Groundnut (s)	CA	Sub surface placement Lateral spacing: 60 cm Dripper spacing: 45 cm Dripper discharge: 4 lph Operating pressure: 1.2 kg/cm^2	Alternate day Jan- March 1hrs April- June 1 hrs 30 minute	29% YI 28% WS
Groundnut (s)	Water stress	-	-	Drip was found better than sprinkler and surface methods Stress effect was not significant
Groundnut (s)	CA	Porous pipe irrigation was comparable with drip and surface methods of irrigation		
Castor	CA	Lateral spacing: 90 cm Dripper spacing: 60 cm Dripper discharge: 4 lph Operating pressure: 1.2 kg/cm^2	Operating frequency: alternate days	43 YI, 29 WS
Onion (seed) *Pilli patti*	CA Raised bed	Lateral spacing: 145 cm Dripper spacing: 50 cm Dripper discharge: 4 lph Operating pressure: 1.5 kg/cm^2	Operating frequency: Daily 47- 50 minute up to harvest	21% YI

Table 5: Continue…

Crop	Approach	System detail	Schedule	Remarks
Cotton	CA	Lateral spacing: 60 cm Dripper spacing: 60 cm Dripper discharge: 4 lph Operating pressure: 1.5 kg/cm^2		
Sugarcane	CA	Lateral spacing: 100 cm Dripper spacing: 50 cm Dripper discharge: 2 lph Operating pressure: 1.5 kg/cm^2	Operating frequency: alternate days Dec. – Jan.: 72 min Feb.- March: 117-1132 min. April-June: 123-159 min. July: 111 min. Sept.- Nov. : 93-99 min.	
Brinjal	CA	Lateral spacing: 90 cm Dripper spacing: 60 cm Dripper discharge: 4 lph Operating pressure: 1.2 kg/cm^2	Operating frequency: alternate days 1 hr 50 min. Mulching with wheat straw @ 5 t/ha	Water saving: 20%, Additional area: 0.2 ha,
Okra		Lateral spacing: 60 cm Dripper spacing: 60 cm Dripper discharge: 4 lph Operating pressure: 1.2 kg/cm^2	Operating frequency: alternate days 1 hr 45 min.	
Tomato	CA	Lateral spacing: 90 cm Dripper spacing: 60 cm Dripper discharge: 4 lph Operating pressure: 1.2 kg/cm^2	Operating frequency: alternate days 1 hr 45 min.	

With respect to sprinkler, use of macro sprinkler in groundnut (s) and minisprinkler in coriander crops has been recommended for farmers of Saurashtra

region. In case of groundnut, the yield increase was of the order of 34 per cent over surface method of irrigation (Table 6)

Table 6: Sprinkler irrigation technologies for Saurashtra region

Crop	Approach	System detail	Schedule	Remarks
Groundnut (s)	CA	Sprinkler: 12 x 12 m Operating pressure: 2.75 kg/cm^2	11 irrigation 50 mm depth - 1st at sowing - 2nd and 3rd at 14-17 days interval - 4th to 11th at 8-10 days interval	34 % higher yield over surface
Coriander	MS (paired row) 30-60-30 cm	0.8 PEF Lateral spacing: 1.8 m Sprinkler spacing: 2.5 m - Sprinkler discharge- 35 lph - Operating pressure: 1.2 kg/cm^2	50 minutes at an alternate days	

MS: minisprinkler

8

Water Management Research in Middle Gujarat

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The middle Gujarat comprises of Ahmedabad, Kheda, Anand, Vadodara, Panchmahal and Dahod districts situated between 21^0 and 20^0 30' N latitude and 72^0 and 74^0 10' E longitude. Geographical and cultivated area is 31.17 lakh ha and 21.7 lakh ha, respectively. With respect to climate, this area is classified as tropical sub-humid and semi-arid. Based on average annual rainfall, it can be divided into three zones: low (less than 750 mm), medium (750-1150 mm) and high (more than 1150 mm) rainfall zones (Fig. 1). Rain fed area is almost equally distributed in all the three zones. Areas with less than 1150 mm (arid and semiarid) are the problematic areas from crop production point of view. Main characteristics of rainfall influencing crop production are its variability, intensity and distribution, late onset of monsoon, early withdrawal of monsoon and prolonged dry spells during the crop period. In other words, crop failures due to uncertain rains are more frequent in regions with lesser rainfall.

In general, more than 50 per cent of total rainfall is usually received in 3 to 5 rainy days. Such high intensity rainfall results in substantial loss of water due to surface run off which also trigger soil erosion. This run-off water should be harvested in farm pond, check dam or any other water harvesting structures for providing supplementary irrigation at critical growth stage.

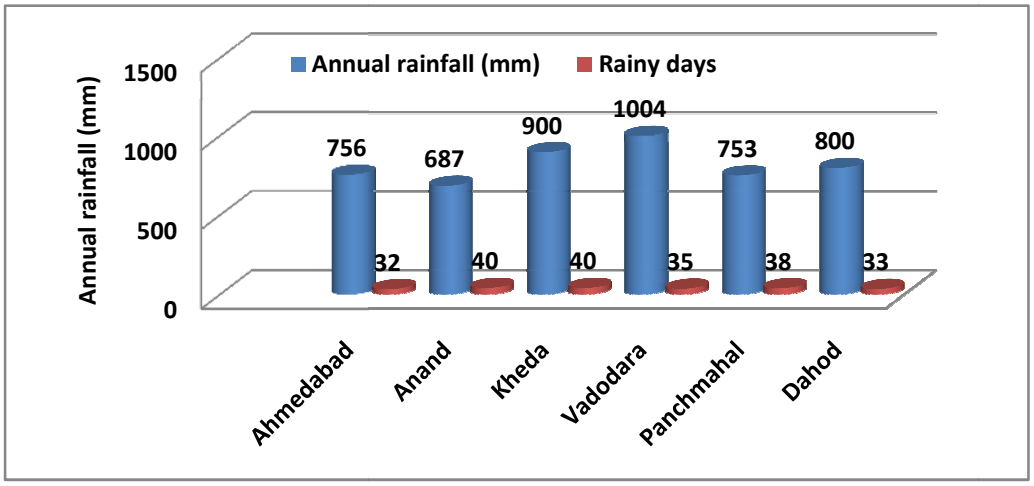

Fig. 1: Average annual rainfall and rainy days of districts of middle Gujarat

[1] *ADR, AAU, Ananad-388 110*

The monsoon season commences from June and recedes in September under the influence of South-West monsoon in the entire region. About 10 to 15 per cent of the rainfall is received in June, nearly 40 per cent in July, 25 per cent in August and 15 to 25 per cent in September months. The maximum number of rainy days are in July and August. The winter is mild cold, whereas, summer is hot. The maximum temperature ranged between 26.0°C and 40.1°C, while, minimum temperature varied from 10.8 °C to 27.4 °C.

Unlike other parts of the state, the agriculture is highly diversified primarily attributed to the adoption of crops amenable and in consonance to climatic situations. As such it becomes necessary to select area specific crops.

In middle Gujarat high value crops like cotton, castor *etc*., have been promoted on irrigated areas with due emphasis on increasing cropping intensity by taking summer crops like groundnut, pearl millet, pigeon pea and vegetables. In low rainfall areas, mixed cropping, intercropping *etc*., is promoted involving crops like pearl millet, pulses, cluster bean *etc*. that provides both insurance against total failure and fodder and food for both animals and human beings. Further, mixed farming has been promoted by including animal husbandry, poultry, agro processing, fisheries, *etc*., as component in agriculture in Panchmahal and Dahod districts.

Soils:

The land is almost a flat plain made up of alluvial soil except in some hilly areas of eastern parts of middle Gujarat adjoining Rajasthan and Madhya Pradesh. The eastern hilly region is consisting of Dahod, Panchmahals districts along with some part of Vadodara district.

Most of the soils in middle Gujarat are medium black to deep black, sandy loam to clay loam and shallow soils in hilly region. However, saline- alkaline soils are encountered in *Bhal* area. District wise soil distribution is presented in table 1 and the important characteristics are given in table 2.

Table 1: Distribution of different types of soils in the districts of central Gujarat

Particular	Ahmedabad	Anand	Kheda	Vadodara	Panchmahal	Dahod
Black soil	10.59	-	*Kyari* 16.56	7.95	-	Deep black shallow 8.60
Clay loam	-	27.83	-	-	-	-
Medium black	35.93	-	23.68	37.34	20.20	-
Loamy Sand	-	-	3.20	15.76	-	-
Sandy loam	20.05	42.60	-	-	26.00	shallow 10.70
Sandy	1.26	-	13.20	4.19	-	-
Hilly light soil	-	-	-	-	8.10	42.70
Saline alkali soil	-	-	1.45	saline 0.58	-	-

Table 2: General characteristics of different soils of central Gujarat

Soil type	Characteristics of soil
Shallow black soil	• Depth ranges from few cms to 30 cms • Light grey colour • Mainly sandy clay loam to clayey in texture
Medium black	• Depth varies from 30 to 60 cm or more • Moderately sub-angular block structure • Light to dark grey colour • Silty clay loam to clayey in texture
Deep black	• Depth 80 cm to few meter • Colour varies from dark brown to very dark grayish brown • Sub-angular block structure • Clayey texture • Poorly drainage
Hilly soil	• Not well developed profile due to steep slope and erosion • Poor fertility • Shallow to moderately deep
Salt affected soil	• Permeability and internal drainage very poor • In Bhal area, generally clay dominated by *smectities* • ESP of soils varies from 1.7 to 77

Fig. 2: Soils of middle Gujarat

Irrigation

Gujarat has enormous oddities in soil, moisture regimes and other natural resources that are reflected in varied agro-climatic situations. The region faces severe scarcity of water, though irrigated farming has picked up over time. The state places lot of emphasis on development of surface irrigation resources through check dams, water reservoirs, watershed management and above all linking of main rivers and development of canal network.

In middle Gujarat, ground water is the major source of irrigation. The surface and ground resources of irrigation water covers the gross irrigated area of 10.73 lakh ha in middle Gujarat and a net irrigated area of 8.37 lakh ha which accounted to 49.45 and 38.57per cnet of cultivated area, respectively. There are three major irrigation projects (Mahi, Kadana and Panam) in the middle Gujarat. In the canal command area, water logging and secondary salinization are the major problems mainly due to negligence of land irrigability nature of the soils. The district and source wise irrigated areas of middle Gujarat are given in table 3.

Table 3: District and source wise irrigated area of middle Gujarat

Districts	Gross irrigated area		(%) Irrigated by source		Net irrigated area (00' ha)	% Net irrigated area
	00' ha	(%)	Surface	Ground		
Ahmedabad	2100	38	25	75	1669	79
Anand	2314	79	42	58	1794	78
Kheda	2556	53	28	72	1951	76
Vadodara	2498	44	10	90	2008	80
Panchmahal	515	17	30	70	421	82
Dahod	749	25	18	82	531	71
Overall	**10732**	**43**	**26**	**75**	**8374**	**78**

Generally, the quality of well water is good in southern part of the state, while tends to become poorer in northern parts. In middle Gujarat, the ground water of the eastern part do not pose much problems. But, the problem of salinity and sodicity tends to increase in western part of the region. Simultaneously, majority of ground waters are either saline or sodic in nature. Even the marginal quality waters have to be used with enough precautions. Ground water table fluctuates at varying locations between 1 to 4 m during annual cycle. The salinity of well water ranges from 0.4 to 36 dS/m, with Na as dominant cation. Whereas, SAR varies from 1 to 62 and RSC ranges from 1.05 to as high as 14.1. Because of low permeability and low or no outfall, high intensity precipitation often cause water stagnation and make huge damage to *kharif* crops particularly in *Bhal* area.

Cropping pattern:

The geographical area of the middle Gujarat is about 16.2 per cent of the state and cultivated area is 21.7 lakh ha. The major crops grown are paddy which occupies 18.4 per cent of the gross area followed by cotton (16.5%), maize (15.3%), pigeon pea (7.4%), pearl millet (6.7%), tobacco (1.8%) and vegetable crops (2.2%). In *rabi,* wheat is a major crop and gram and cumin are cultivated in some areas.

Summer paddy and pearl millet are the dominant crops grown during hot season in middle Gujarat.

Water management technologies for middle Gujarat

Keeping in mind the agroclimatic conditions of middle Gujarat in all 36 water management technologies comprising of surface (20), sprinkler (5) and drip (11) irrigation technologies covering 18 different crops have been developed and recommended for adoption by the farmers.

Surface irrigation technologies

Under this method of irrigation, cereals (wheat, rice, maize), pulses (gram, pigeon pea, cluster bean), oil seeds (mustard, castor), cash crop (cotton) and vegetables (okra, tomato, brinjal, cabbage) crops were studied and agroecological situation based irrigation schedules were developed (Table 5). For developing appropriate irrigation schedules for each crop, mostly climatological approach (CA) was followed, However, under limited water availability situation critical growth stage (CGS) approach was also followed for scheduling of irrigation in crop like wheat, gram, cotton *etc*., Simultaneously, more comprehensive approach *viz.*, soil-crop-climate (SCC) was also tested in some crops particularly under SSP command. Ofcourse, both climatological and soil-crop-climate approaches were comparable with each other in terms of number and schedule of irrigation. With the application of 2 to 3 irrigations to *kharif* or late *kharif* crops like pigeon pea, cotton, cluster bean, castor *etc.*, showed considerable increase in yield and ultimately the net income. While for vegetable crops grown during *rabi* season, irrigation schedules were developed in presence of mulching. The mulching material *viz.*, black plastic and crop residue (paddy straw or sugarcane trash) were tested and even black plastic was found remunerative in brinjal and tomato crops. Across the vegetable crops studied, in general the numbers of irrigation vary between 9 and 12 under middle Gujarat conditions. In wheat crop, irrigation schedule was developed by using canal and tube well water conjunctively. This was specially attempted for enabling the use of poor quality ground water in canal command as well as for mitigating adverse effect of sole use of poor quality waters on soil health.

Table 4: Surface irrigation technologies for middle Gujarat

Crop	Zone	AES	Approach	Irrigation (Nos./ Depth : mm)	Irrigation schedule	Remarks
Wheat	III	III	CGS	5 (60)	Sowing, CRI, milking, dough and grain filling	Higher yield and net profit
				4	Sowing, CRI, flowering and dough stage	Save water
Wheat (conjunctive use)	III	III	CGS	5	Sowing, CRI, tillering, flowering and grain filling	Irrigated canal and ground water alternately

Crop	Zone	AES	Approach	Irrigation (Nos./ Depth : mm)	Irrigation schedule	Remarks
Rice	III	II	SRI	-	- Keep soil moist, it required drain out standing water - Keep 5 cm standing water from panicle initiation to dough stage	- Water saving - Higher yield - Less cost of cultivation
Maize	III	II	CA	7 (60)	At sowing, second 6 days after sowing and remaining 5 at 20 DI	N : R : 120 : 60 kg/ha
Maize	III	II	Moisture conservation	Rainfed	Ridge 60 width, 30 cm deep at every 2 cm across the furrow.	Higher yield and net return.
Gram	III	III	CGS	1	At branching	Higher yield and net profit
	III	IX	CGS	2	At sowing and flowering	Higher yield and net profit
Pigeon pea (*rabi*)	III	II	CGS	2 (60)	At branching and pod formation	Higher yield and net profit
				1 (60)	At branching only	Higher yield and net profit
Pigeon pea	III	IX	SCC	2	One month after cessation of monsoon and second 35 days after first	SCC approach has wider adaptability
Cluster bean (late *kharif*)	III	II	CGS	2	At branching and flowering	Seed and vegetable purpose
Cluster bean	III	II	CGS	2	At branching and flowering (If rainfall not received during this stage)	Apply 5 t FYM/ha + 20 : 40 NP kg/ha + 20 kg elemental S/ha as basal
Mustard	III	III	CGS	4 (50)	At sowing, node elongation, flowering and pod development	Mulching with black plastic increased yield but was not economical.

Table 4: Continue…

Crop	Zone	AES	Approach	Irrigation (Nos./ Depth : mm)	Irrigation schedule	Remarks
Castor (late *kharif*)	III	II	CA	5 (50)	At sowing and remaining 4 at interval of 25 to 30 days in all furrow	Mulching with black plastic increased yield but was not economical.
Cotton (*deshi*)	VIII	II	CGS	2 (60)	At 20 and 40 days after withdrawal of monsoon	- *Bhal* area - Higher yield and net income
Cotton	V	III	CGS	2	At flowering and boll formation	- Alternate furrow - Fertilize @ 80 kg N/ha in two splits - Higher yield
Cotton (*deshi*)	III	IX	SCC	3	First at one month after cessation of monsoon, second 45 days after first and third 25 days after second	SCC approach wider adaptability
Okra	III	II	CA	9 (60)	At sowing, subsequent 2 at 9-10 days interval and rest 6 at weekly interval	Apply N @ 150 kg/ha
Okra	III	II	CA	10 (60)	At sowing, at 10-12 days interval upto March and at weekly interval then after	- Mulching with sugarcane trash @ 5 t/ha - Yield increased by 25%
Tomato	III	II	CA	11 (60)	At sowing, at 15 days interval during Dec. and Jan. and subsequent at 11 days interval Feb. up to picking	- Mulching with paddy straws or black plastic increased yield and net income

Crop	Zone	AES	Approach	Irrigation (Nos./ Depth : mm)	Irrigation schedule	Remarks
Brinjal	III	IX	CA	12 (80)	At transplanting, next 3 at 10-12 DI, next 5 at 15-17 DI and last 3 at 10 DI	- Mulching with black plastic (50 u and 80 % coverage) or wheat straw @ 10 t/ha increased yield and income - Mulching is to be done one month after transplanting
Cabbage	III	IX	CA	6 (80)	At transplanting, second one week later and rest at 26 days interval	Apply N @ 200 kg/ha

CA: Climatic approach, CGS: Critical growth stage, AES: Agro-ecological sub region

Micro irrigation technologies

Though, middle Gujarat possesses Mahi-Kadara and Padam as major irrigation projects with 5.12 lakh ha command area, yet there is enough ground water potential to be used for irrigation purpose. Accordingly, micro irrigation comprising drip (Table 3) and sprinkler (Table) irrigation technologies have been developed and covering 16 different crops which predominantly includes vegetable and fruit crops. Apart from irrigation, scheduling for fertigation with water soluble and liquid fertilizer technologies has also been developed for some crops.

The drip irrigation technologies for field crops *viz.*, sweet corn and castor (late *kharif/rabi*) were developed apart from irrigation schedule in castor crop fertigation schedule and mulching with paddy straw were recommended for achieving higher castor seed yield and net profit. In castor, paired row planting was recommended for reducing the cost of drip system. In the case of vegetable crops viz., okra (s), tomato, brinjal, cabbage-okra (s) sequence and cabbage, the drip irrigation schedules were developed and recommended for the farmers. Not only this, but triple row planting of okra (s) and paired row planting in tomato and cabbage were also tried for cost reduction of drip system and recommended for the farmers. In general, using either water soluble or liquid fertilizer, fertigation schedule with 5 to 6 splits in cabbage, okra and tomato and 10 splits in brinjal crop were also standardized and recommended for the farmers so as to achieve higher yield along with saving of water and fertilizer. Similarly, drip irrigation schedules for papaya, guava and

kagzilime have also been developed. For papaya, along with drip irrigation, fertigation schedule was also developed and recommended for the farmers.

For the close grown crop like wheat, maize (*rabi*), gram, cabbage and onion *etc.*, where drip system becomes costly, sprinkler irrigation technologies have been recommended. Adoption of sprinkler method of irrigation resulted in about 50 per cent saving in water along with considerable increase in yield. This technology proved more effective in the area where limited availability irrigation water situation. In crop like onion, irrigation and fertigation schedules have been developed using mini sprinkler system.

Scientific and most efficient use of irrigation facilities whatsoever may exist in areas have attained great significant. Irrigation should be applied in different crops as per the recommendation using adequate quantity, proper method and time of application. All these aspects play vital role in the efficient use of water. Outline of research recommendations pertaining to water management through sprinkler is outlined below.

Table 5: Drip irrigation technologies for some crop of middle Gujarat

Crop	Zone	AES	Appr oach	System details	Operating pressure and time	Remarks
Sweet corn	III	II	CA	- Lateral spacing : 0.9 m - Dripper spacing : 0.6 m - Dripper discharge : 4 LPH	1.2 kg/cm2 2 hrs on alternate day	- Higher yield and net income
Castor	III	II	CA	- Lateral spacing : 2.4 m - Dripper spacing : 0.6 m - Dripper discharge : 4 LPH	- 1.2 kg/cm2 - 100 to 150 min. on alternate day	- Paired row (60 : 60 : 180 cm) - 30 % N and 100% P as basal - 70 % in 3 equal splits and monthly interval as fertigation.
Castor	III	II	CA	- Lateral spacing : 2.4 m - Dripper spacing : 0.6 m - Dripper discharge : 4 LPH	- 1.2 kg/cm2 - Time : 90 min to	- Paired row - Mulching with paddy straw @ 5 t/ha increased yield
Okra (S)	III	II	CA	- Lateral spacing : 1.2 m - Dripper spacing : 0.6 m - Dripper discharge : 4 LPH	Pressure - 1.2 kg/cm2 - Time : 1 hr 50 min two days interval	-100 kg N and 25 Kg K/ha as water soluble fertilizer in 6 equal splits starting from 21 DAS at 6 DI -Triple row 30: 15:60

Table 5: Drip irrigation…….

Tomato	III	II	CA	Lateral spacing : 1.2 m - Dripper spacing : 0.6 m - Dripper discharge : 4 LPH	Pressure - 1.2 kg/cm2 - Time : 36 min day Nov-Dec. 45 min day Jan-Feb 70 min day March-April	-Paired row- 45:25:45 cm - 37.25: 18.25: 31.25 N: P: K kg/ha as water soluble fertilizer in 6 equal split starting from 21 DAS at 5 day interval
Brinjal	III	II	CA	Lateral spacing : 0.9 m - Dripper spacing : 0.6 m - Dripper discharge : 4 LPH	Pressure - 1.2 kg/cm2 - Time : 35 min day Oct. 25 min day Nov-Jan.	-20t FYM/ha -Use liquid fertilizer apply in 10 equal split starting from 21 DTP at 6 DI @ 50:25 kg N: P/ha
Cabbage-Okra sequence	III	II	CA	Lateral spacing : 0.9 m - Dripper spacing : 0.6 m - Dripper discharge : 4 LPH	Pressure - 1.2 kg/cm2 - Time : 50 min on alternate day	-Water saving: 50 % -Yield increase: 28 %
Cabbage	III	II		Lateral spacing : 1.2 m - Dripper spacing : 0.45 m - Dripper discharge : 4 LPH	Pressure - 1.2 kg/cm2 - Time : 43 min on alternate day	-Paired row: 45: 75: 45 cm -Apply N: P: K @ 60: 60: 60 N & P as Urea/SSP and K as MOP/ha -Apply in 5 equal split starting from 15 DATP at 10 days interval
Papaya	III	II	CA	Lateral spacing : 2.5 m - Dripper spacing : 2 dripper/plant at 45 cm away on either side of plant - Dripper discharge : 4 LPH	Pressure - 1.2 kg/cm2 - Time : 5 hr 30 min during Sept to Feb, 10 hrs 40 min during March to on set of monsoon	-Apply N as Urea, P as phosphoric acid and K as MOP @ 160: 160: 200 g/plant -Apply in 6 equal split starting from 60 DAP at 15 DI

Table 5: Continue….

Guava	III	I X	CA	4 dipper/tree Dripper discharge: 4 LPH	Pressure - 1.2 kg/cm2 Time: 5hrs 30 min during Oct - Dec. Or 3 hrs during Oct-Dec.	
Kagzilime	III	IX	C A	Lateral spacing : - Dripper spacing : 4 /tree 1 m away from trunk - Dripper discharge : 4 LPH	Pressure - 100 KP Time: Jan. - 2hrs, Feb.- hrs, March - 4 hrs, April - June. 5 hrs, July - Sept. - 2 hrs (dry spell), Oct - Dec. - 3 hrs.	

Table 6: Sprinkler irrigation technologies for some crops of middle Gujarat

Crop	**Zone**	**AES**	**Approach**	**Irrig. No. D: mm**	**System details**	**Irrigation schedules**	**Remarks**
Wheat	III	II	CA	5	- Spacing : 12 m x 12 m - Pressure : 2.75 kg/cm2 - Application rate : 1.67 cm/hr - Operational time : 3 hrs.	- At sowing, remaining 4 at 20-21 days interval	- Water saving 56 % - Under limited water availability condition.
Maize (rabi)	III	II	CA	5	- Spacing : 12 m x 12 m - Pressure : 2.75 kg/cm2 - Application rate : 1.67 cm/hr - Operational time: 3 hrs.	-AS and 6 irrigation at 17 DI - AS and 4 at 25 DI	-Yield increase: 27 % - Increase Net income : 38 % - Water saving : 26 %

Table 6: Continue…..

Crop	Zone	AES	Approach	Irrig. No. D: mm	System details	Irrigation schedules	Remarks
Gram	III	IX	CA	3 (50)	- Spacing : 12 m x 12 m - Pressure : 2.75 kg/cm2 - Application rate : 1.67 cm/hr - Operational time : 3 hrs.	AS, 25-30 DAS and 45-50 DAS or only one at branching under constraint of water availability.	- Water saving 53% - Yield increase : 69% - Water saving 68 %
Cabbage	III	II	CA	7	- Spacing : 12 m x 12 m - Pressure : 2.75 kg/cm2 - Application rate : 1.67 cm/hr - Operational time : 2.5hrs.	AS (60 mm) rest of 40 mm at 10-12 DI	
Onion	III	II	CA	10	- Spacing : 2.5 x 2.5 m - Operational pressure : 1.75 kg/cm2 - Operational time : 5 hr 30 min.	80 mm at TP, second of 50 mm at 6 to 7 DATP Subsequently 6 irrigation at 12-15 DI rest 2 at 8-10 DI	Fertilizer @ 100 % RDF 50 % N as basal, remaining N in 5 equal splits at 10 DI starting from 30 DATP

DI: Interval in days

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Technologies for Water Management in Sardar Sarovar Project Command

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Gujarat, with a total geographical area of about 196 thousand km^2, has got 94 lakh ha as net sown area. Out of this, around 30 lakh ha area is under irrigation working out to per cent net irrigated area of 42.3. Around 78 per cent of the irrigation is done through wells and tube wells and the rest through surface water.

The state has 25 major irrigation projects of which 6 are located in South Gujarat, 7 in middle Gujarat, 8 in North Gujarat and 4 in Saurashtra. The Mahi-Kadana Project on river Mahi in middle Gujarat with a CCA of 2.6 lakhs ha and Ukai-Kakrapar Project on river Tapi in South Gujarat with a CCA of 3.43 lakhs ha contribute to the bulk of canal command area in the state. Apart from this, the Sardar Sarovar Project will bring an additional area of about 18 lakhs ha under irrigation in future. The details regarding SSP command and technologies generated for this area are elaborated here.

Status of canal net work:

The Sardar Sarovar is the biggest multipurpose project built on river Narmada. This project has total canal length of 74626 km. Out of the total length of canal, the length of distributories, minor and sub minors are completed is less than 50 per cent. However, main canal and branch work is almost completed.

Table 1: Status of canal net work in SSP Command

Type of canal	Total length of canal (km)	Canal length completed (km)	% of canal length completed
Main canal	458	458	100
Branch	2585	2089	81
Distributaries	5112	2201	43
Minor	18413	5852	32
Sub minor	48058	10168	21
Total	**74626**	**20768**	**28**

Agro-climatic based regions of SSP Command

The SSP Command is spreads in Bharuch, Vadodara, Kheda, Ahmedabad, Gandhinagar, Mehsana, Patan, Banaskantha, Bhavnagar, Surendranaga and Kutch districts of Gujarat. The districtwise command area of SSP given in fig.1 and table 2 indicates that maximum command area of 3.40 ha is in Vadodara districts.

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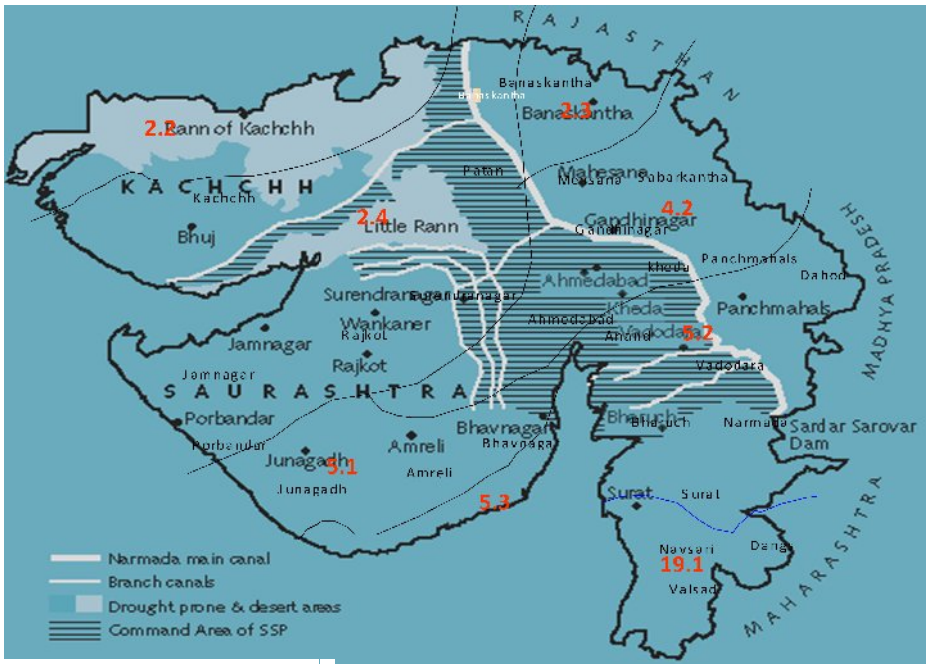

Fig. 1: Agroecological subregions wise command area of SSP

Table 2: The districtwise distribution of area under SSP command

SN	District	Area covered (in lakh)
1	Ahmedabad	3.30
2	Banashkantha	3.13
3	Bharuch	0.08
4	Bhavnagar	0.48
5	Gandhinagar	0.10
6	Kheda	1.16
7	Kutch	0.37
8	Mehsana	1.50
9	Panchmahals	0.10
10	Rajkot	0.34
11	Surendranagar	3.04
12	Vadodara	3.40
	Total	**18.00**

Source: Anon. 1991

The climatic variation ranges from arid in Kutch and Banaskantha districts to semi arid in districts of middle Gujarat. Similarly, there is considerable variation in soil type i.e. sandy in North Gujarat area to loamy soils in middle Gujarat area of the command. Ofcourse, clay soils are also encountered in some parts of Bharuch, Ahmedabad, Bhavnagar, Surendranagar and Patan districts. Based on agroclimatic parameters whole of the SSP command area is divided in to 13 regions (Table 3). The region wise land irrigability classes of soil s reported in table 3 clearly suggest that in most of the regions conventional methods of irrigation can be practiced. Similarly, from ground water quality point of view also, except Sankheda-Savali and Sinor-Vadodara regions, the quality is either medium or poor. Because of this, there is need to take special care while adopting any irrigation method.

Table 3: Region wise LIC and water quality in SSP command

Region No.	Name	LIC	Water Quality Rating	Remarks
1	Sankheda-Savli	1-3	Good	Normal irrigation
2	Sinor-Vadodara	1-2	God	Normal irrigation
3	Bharuch-Amod	2-3	Medium	Restricted irrigation
4	Vagra-Jambusar	2-6	Poor	No flood irrigation, Special care needed
5	Mehmadabad-Daskroi	1-3	Medium	Restricted irrigation
6	Sanand-Kadi	1-3	Medium	Restricted irrigation
7	Dholka-Dhanduka	5-6	Poor	No flooding, special care needed
8	Limbdi-Botad	2	Medium	Restricted irrigation
9	Halvad-Malia	2	Medium	Restricted irrigation
10	Viramgam-Dasada	1	Poor	Restricted irrigation
11	Sami-Harij	1-4	Poor	Very restricted irrigation
12	Radhanpur-Vav	3	Poor	Very restricted irrigation
13	Rapar-Mundra	2-3	Poor	Very restricted irrigation

LIC: Land irrigability class

Source: NPG, GOG

Technologies for SSP Command

During phase-I, the irrigation water management related work was initiated at Khandha centre. This centre represents the high clay containing soils of the SSP command. The technologies developed for different crops grown in high clay containing soils along with some new potential crops in the area are given in table 4.

Table 4: Water management technologies for clay soils (*Phase- I, Khandha)*

Crop	Method of irrigation	Number of irrigation	Recommended schedule of irrigation
Wheat	Surface	7	- First irrigation just after dry sowing - Second irrigation at 19-20 days after first one - Remaining five irrigations should be given at an interval of 12-13 days
	Surface		Check basin size border length: 60 m width: 2.0m flow rate: 2 to 5 lit/second
	Sprinkler	7	- First irrigation of 80 mm on the day of sowing - Second of 50 mm 17 days after first one - Third and fourth of 50 mm at an interval of 13-14 days - Remaining three irrigation at an interval of 10 days
	Surface	4 (CGS)	- First two irrigation at post sowing and crown root initiation - Next two at tillering and panicle initiation or flowering or milky stages
Sorghum	Surface	4 (CGS)	- After sowing - At knee high stage - At flag leaf stage - At flowering stage
Gram	Surface	-	Basin size - Length: 8 m - Width: 4 m
	Surface	2 (CGS)	- After sowing - At flowering stage
	Sprinkler	3	- At time of sowing - Second at 25-30 days after sowing (branching) - Third at 45-50 days after sowing (pod formation)

Table 4: Continue….

Crop	Method of irrigation	Number of irrigation	Recommended schedule of irrigation
Pigeon pea (*kharif*)	Surface	3	- First one month after cessation of monsoon - Second at two months after cessation of monsoon - Third at three months after cessation of monsoon
	Surface	2 (CGS)	- First one month after cessation of monsoon - Second at 35 days after first irrigation
Pigeon pea (*Rabi*)	Surface	6	- The first immediately after sowing - Next four irrigation at weekly interval - last at three week after the fifth irrigation
Brinjal	Surface	12	- First irrigation at the time of transplanting - The next three irrigation should be at an interval of 10-12 days - Remain five irrigations at 15-17 days - last three at 10 days interval
Tomato	Drip + mulching	-	***System details:*** Lateral spacing: 90 cm Dripper spacing: 120 cm Dripper discharge: 4 lph Operating pressure: 1.2 kg/cm^2 Operating frequency: alternate day Operating time: November to January: 1.0 hrs February to March: 1 hrs and 30 minutes ***Mulching:*** - Mulching one month after transplanting - Black plastic mulch of 50 micron thickness - Area coverage: 80%
Chillies	Surface	7	- First after cessation of monsoon - Rest at 20-25 days interval

Table 4: Continue…..

Crop	Method of irrigation	Number of irrigation	Recommended schedule of irrigation
Cotton	Surface + Mulching		- First irrigation should be given one month after cessation of monsoon - Rest of the irrigation given at an interval of 18-21 days - Use of either wheat straw @ 10 t/ha or black plastic (50 micron) as mulch was also recommended.
Cotton	Drip + fertigation		***System details:*** Lateral spacing: 120 cm Dripper spacing: 90 cm Dripper discharge: 4 lph Operating pressure: 1.2 kg/cm^2 Operating frequency: alternate day Operating time: 2 hrs and 15 minutes ***Fertigation:*** - **A**pply 75 per cent of RDN (*i.e.* 180 kg N/ha) in the form of urea - Number of splits: 10 - Frequency: at weekly interval - Commencement: one month after sowing
Castor (*kharif*)	Surface	4	- First irrigation 40 days after cessation of monsoon - Second after 20-25 days after one and remaining two at an interval of one month
Mustard	Surface	4	- First at sowing - The rest of irrigation should be given at four weeks interval
Guava (6-8 year old)	Drip	-	***System details:*** Lateral spacing: one lateral between two rows No. of dripper per tree: 4 Dripper discharge: 4 lph Operating pressure: 1.2 kg/cm^2 Operating frequency: alternate day Operating time: October to December: 5.0 hrs and 30 minute *For limited water situation* October to December: 3.0 hrs
Pomegranate	-	-	In high clay containing soils of SSP command, planting of pomegranate is not recommended due to fruit cracking and heavy infestation of *cercospora* disease.

Apart from developing irrigation schedule for individual crop, some crop sequences were also recommended based on the availability of irrigation water in SSP command (Table 5).

Table 5: Water availability based recommended crop sequences in SSP command

Soil type	**Representative Area**	**Assumed Water availability (mm)**	**Crops/cropping sequence**
Bara Tract	Problematic soils in the Vagra and Jambusar talukas of Bharuch district	~350 mm	*Kharif* :Cotton/Tur *Rabi*: Wheat/gram/pulses/ Mustard/pigeon pea/castor Brinjal/Tomato Ber/ Sapota
Black soil	Karjan taluka of Vadodara district	~ 450 mm	*Kharif* :Cotton/Castor *Rabi*: Tur/ Gram/ other pulses/ Mustard Tomato/Brinjal Mango/Sapota/Ber/Guava
Sandy loam	Thasra taluka of Kheda district	~ 450 mm	*Kharif*:Cotton/Castor *Rabi*: Wheat/Mustard/Groundnut Tomato/Potato/Brinjal/Cabbage/ Chillies Lime/Mango

After completion of phase-I, during phase-II four centres *viz*., Tanchha (Bharuch), Dabhoi (Vadodara), Thasra (Kheda) and Dandhuka (Ahmedabad) representing different agroclimatic conditions of SSP command were established in the year 2006. At each centre, considering the water availability, predominent crops of the area, soil type *etc*., number of soil and water management technologies were developed under the technical guidance of Soil and Water Management Research Unit, NAU, Navsari. The centre wise technologies developed are reported in table 4.

Table 6: Center wise soil and water management technologies recommended in SSP command (Phase-II)

a) ARS,NAU, Tanchha (clay soils)

Crop	Land/irrigation aspect	No. of irrigation	Recommended treatment
Cotton (*kharif*)	Land configuration	RF	- Open 22.5 cm deep furrow after four or two rows of cotton planted at 1.2 m spacing
Cotton (*kharif*)	Soil management	RF	- Apply either FYM @ 10 t/ha or Gypsum 6 @ t/ha or Pressmud 6 @ t/ha before sowing
Castor (late *kharif*)	Surface method	-	*Limited water availability* - Apply alternate furrow irrigation - Mulch crop with 50 micron black plastic with 50 per cent area coverage
Gram	Surface method CGS	1	*Limited water supply* - Give only one irrigation either at sowing or branching

b) ARS, Dabhoi, AAU, (loamy soils)

Crop	Land/irrigation aspect	No. of irrigation	Recommended treatment
Mustard (*Rabi*)	Surface method CGS	4	- First at sowing - Second at node elongation - Third at flowering and - Fourth at pod development
Wheat (*Rabi*)	Surface method	5	- First at sowing - Second at 15-20 days after sowing - Rest three (3) irrigations at an interval of 12-13 days (for all irrigation)
Castor (*Kharif*)	Surface method	4	- First after cessation of monsoon - Second at 25 days after first irrigation - Remaining two (2) at monthly interval
Gram (*Rabi*)	Surface method CGS	1	- Irrigate either at sowing or at branching using canal water keeping 40 mm depth

Wheat	Surface method CGS	5	- First at sowing - Second at crown root initiation - Third at grain filling stages - Fourth at milking stages - Last at dough stage
Gram	Surface method	2	*Limited availability* - First at branching - Second at pod formation stages, (Apply 75 % of RDF)

c) ARS, Thasara, AAU (Loam to sandy loam)

Crop	**Land/irrigation aspect**	**No. of irrigation**	**Recommended treatment**
Castor (Late *kharif*)	Surface method	5	- Apply irrigation in all furrow at an interval of 25-30 days - Use black plastic (50 micron) as mulch was not found economical
Maize (*Rabi*)	Sprinkler method	7	- First at the time of sowing - Remaining six irrigations at an interval of 17 days *System details:* Sprinkler spacing : 12 x 12 m Application rate: 1.67 cm/hr Operating pressure: 2.75 kg/cm^2 Operating time: 3 hrs
Cabbage-Okra (Sequence)	Drip method	-	*System details:* - Lateral spacing: 90 cm in alternate row - Dripper spacing : 60 cm - Dripper discharge:4 lph - Operation: alternate day - Operating pressure:1.2 kg/cm^2 Operating time: Cabbage:50 min. Okra: 100 min.
Mustard	Surface method CGS	4	- First at sowing - Second at node elongation - Third at flowering stages - Fourth at pod development stages
Gram	Surface method	1	- Apply only one irrigation to gram crop at branching (Apply FYM @ 10 t/ha + 37.5 kg P_2O_5 at the time of sowing

d) ARS, Dhandhuka, AAU (Clay and salt affected soils)

Crop	Land/irrigation aspect	No. of irrigation	Recommended treatment
Cotton (*kharif*)	Land configuration	RF	- Open 22.5 cm deep furrow after every four or two rows of cotton planted at 1.2 m spacing
Cotton (*kharif*)	Soil Management	RF	*Problematic soil* - Apply of gypsum + FYM @ 3 t/ha
Ber	Drip method	-	*For established ber tree* *System details:* - Lateral spacing : 6.5 m - Dripper spacing : 50-100 cm away from the trunk of the tree - No. of dripper/tree: 10 - Dripper discharge: 4 lph - Operating pressure: 1.2 kg/cm^2 Operating time :105 min. after cessation of monsoon till harvest
Castor	Surface method	-	- Apply irrigation in alternate furrow with black plastic mulch (50 micron) with an area coverage of 50 per cent

RF: rainfed, CGS: Critical crop growth stage, RDN: Recommended dose of Nitrogen