BUILDING INFORMED AND SCALABLE WATER SECURITY SOLUTIONS FOR GUJARAT

Key Insights and Recommendations

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INTRODUCTION AND OVERVIEW OF THE STUDY

CONTEXT

Gujarat is a water-scarce state and at present, has only 2% of the country's water resources with 5% of the country's population. There is considerable variation in the available quota of surface water. South Gujarat, Saurashtra and Kutch, and North Gujarat have water resources of 69%, 17%, 3%, and 11% respectively. The rainfall pattern throughout the state is erratic and uneven which leads to imbalances in agriculture growth and livelihoods.

Several studies have been conducted on the Status of Water Resources in Gujarat. They have indicated the regional disparities in availability and demand for water (surface and groundwater), and also recommended appropriate measures. However, a holistic perspective on water management including the interrelationship between water (surface water, irrigation infrastructure and groundwater), water quality, soil health, agriculture and animal husbandry has not been adequately brought out.

Groundwater, surface water and soil moisture form a critical trinity of sources for any effective water management solution. There is a need for evolving a comprehensive framework that can enable practitioners and policymakers to diagnose several variables (indicated above) that affect water security in a region.

ABOUT THE STUDY

The Development Support Centre and DSC Foundation in partnership with Hindustan Unilever Foundation have conducted a study on "**Building informed and scalable water security solutions for Gujarat**". The study was conducted with the help of knowledge institutions such as ACWADAM, Pune and INREM Foundation, Anand. It was steered by a committee comprising eminent water management experts from Government, Civil Society Organisations and Academic Institutions. The study was carried out from June 2020 to March 2022 by a Multi-disciplinary team at DSC and 14 field researchers.

OBJECTIVES OF THE STUDY

The main objectives of the study were to:

i. Assess the current status of water resources, soil health, agriculture, and animal husbandry in Gujarat.
ii. Ground truth the secondary data with primary data collection and highlight the variance if any.
iii. Establish a relationship between thematic parameters such as Groundwater, Surface water, Rainfall and Cropping patterns to enable decision-making.
iv. Establish water typologies and water security scenarios for each region and state.
v. Develop region-specific solutions framework for the future that can be driven through Government, Private Sector, Civil society, and Community participation and implemented at scale.

Seven parameters were considered for the study. These are I. Rainfall, ii. Surface Water, iii. Irrigation Infrastructure, iv. Ground Water and its quality, v. Soil Type and its quality, vi. Agriculture and vii. Animal Husbandry.

The secondary data collected was in various formats and had many inconsistencies in terms of their availability and units. Hence after studying all the datasets, the secondary data was standardized in a uniform format at the district level. For the interrelationship and comparison of thematic parameters within the region and with different regions, various statistical methods including the principle of normalization were used. Advanced remote sensing and GIS tools were applied for generating, visualizing, analysing, and interpreting the thematic parameters.

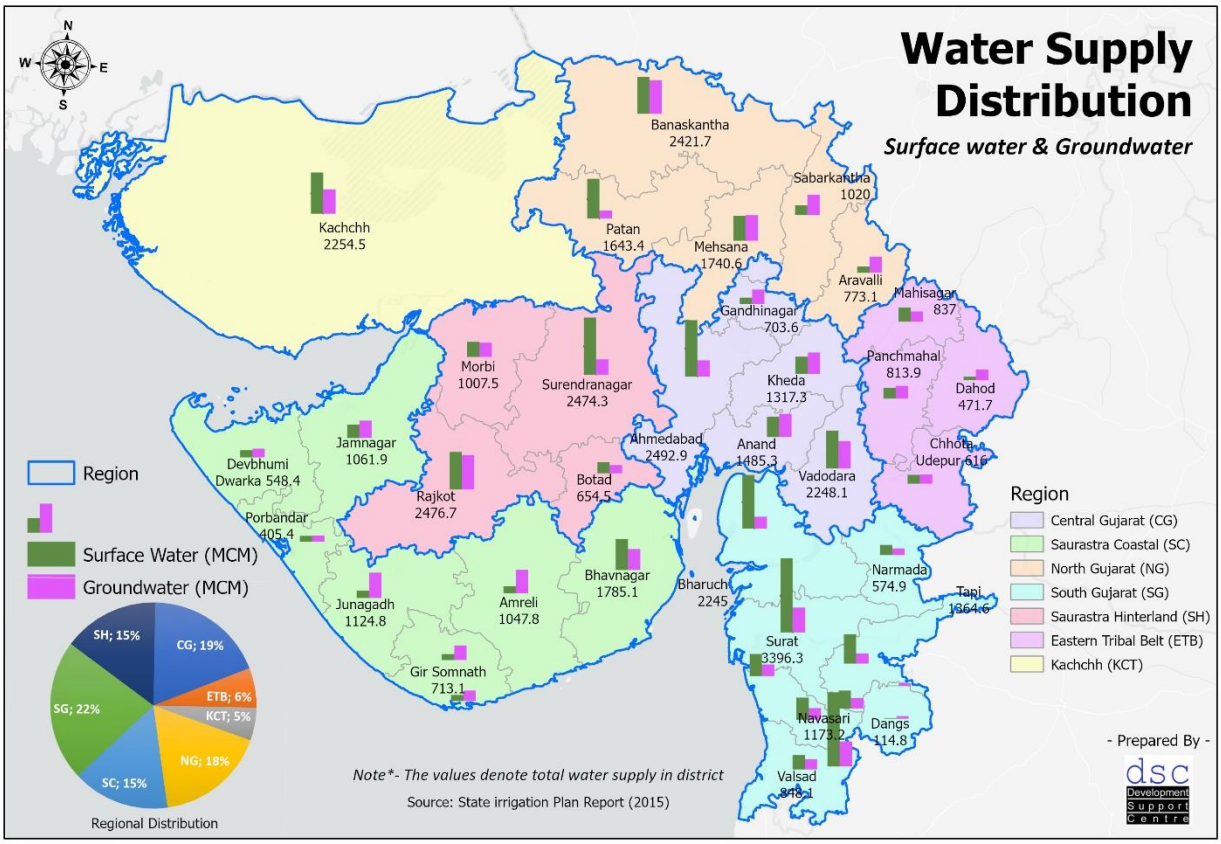
STUDY REGION AND METHODOLOGY

Based on the static parameters i.e., rainfall, soil type and geology, the state was categorized into seven regions i.e., i. North Gujarat, ii. Central Gujarat, iii. Eastern Tribal Belt (ETB), iv. South Gujarat, v. Saurashtra Coastal, vi. Saurashtra Hinterland and vii. Kachchh. Primary data was collected from 12 representative watersheds, covering 108 sample villages and 877 Households across the state. Soil and Water testing were carried out with each household to validate the secondary data. This Summary is derived from the detailed report of Gujarat and all the regions. The report also documents some of the best practices of farmers and studies carried out by Civil Society Organisations.

KEY INSIGHTS

Water Supply (Surface + Groundwater)

The highest water supply (surface + groundwater) is seen in South Gujarat (22%) followed by Central Gujarat (19%) and North Gujarat (18%) while the lowest is seen in ETB (6%) and Kachchh (5%). At the district level, the highest water availability (MCM) is seen in Surat, Ahmedabad, Rajkot, Surendranagar and Banaskantha while the lowest water supply (MCM) is seen in Dang, Porbandar, Dahod, Devbhumi Dwarka and Narmada.



The Per Hectare Availability of water in the state is 0.0038 mcm/ha. 9 districts mostly in South and Central Gujarat had above the state average water availability. 24 districts had low water availability and the least water available was **in Dahod (0.0012MCM/ha), Dang (0.0014MCM/Ha), Amreli (0.0018MCM/Ha) and Banaskantha (0.0019MCM/Ha)**

Groundwater Development

As per CGWB 2019 Annual report, four districts i.e., Mahesana, Patan, Banaskantha and Gandhinagar are classified as over-exploited. While five districts i.e., Kachchh, Aravalli, Porbandar, Sabarkantha and Ahmedabad are classified as semi-critical, and the rest are under the safe zone.

Rainfall & Groundwater Relationship

The average rainfall from 1995 to 2020 is 821 mm however there is spatial variation between different regions. The highest rainfall is seen in South Gujarat (1034 to 2358 mm) and the lowest is seen in Kachchh, Banaskantha, Patan, Morbi, Surendranagar, Botad and Bhavnagar districts (456 to 634 mm). The rainfall trend from 1995-2020 shows a five-year rainfall cycle wherein an increase in rainfall is followed by a decrease and vice-versa. A majority of the regions have seen an increase in rainfall between 2015-2020.

The rainfall and groundwater trend for the period 1995 to 2020 was studied and correlated. The result shows that despite an increase in rainfall from 547 mm in 1995 to 657mm in 2020 in North Gujarat, there is a decline in groundwater levels from 23 metres to 35 metres (52% decrease). A similar condition is also observed in CG wherein the rainfall trend is increasing (from 685 mm to 825 mm) there is a decline in the groundwater level from 21 metres to 25 meters (20% decrease).

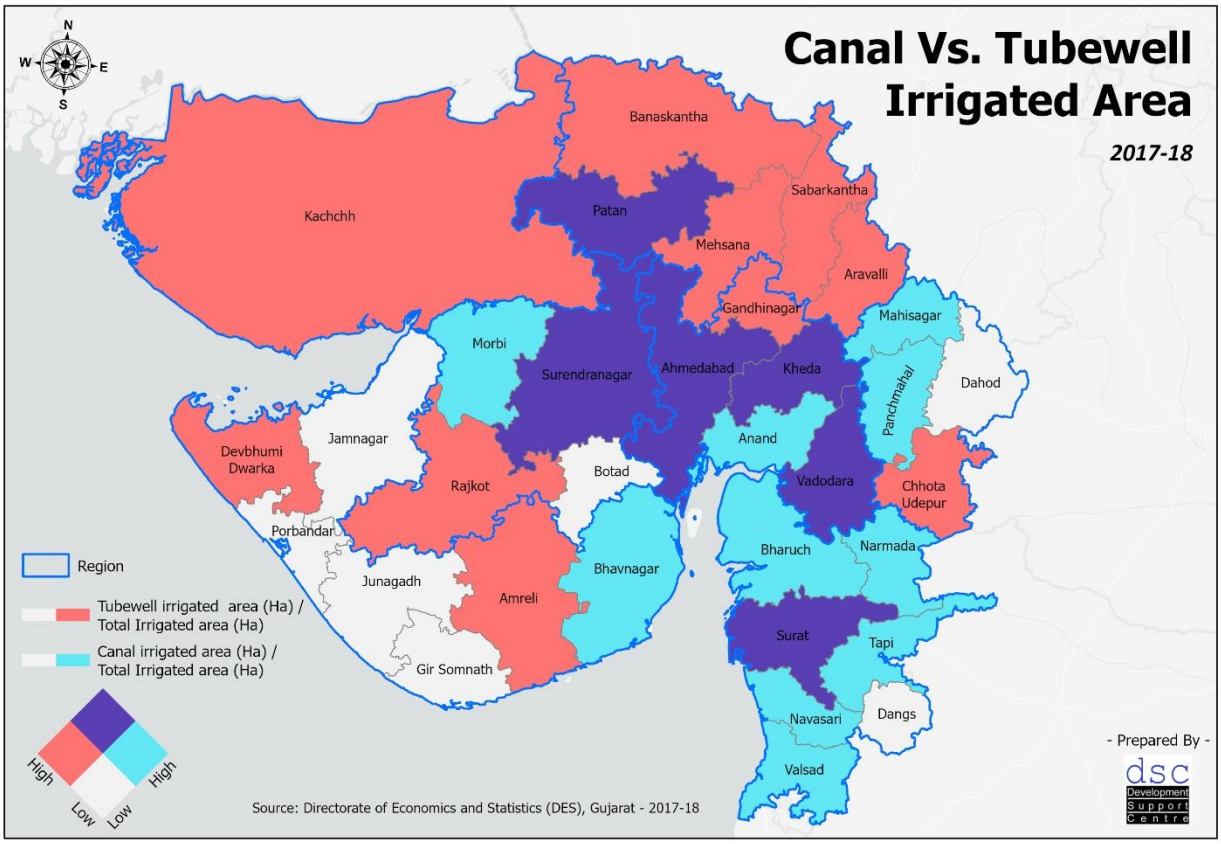
Region	Rainfall trend	Groundwater Level fluctuation
North Gujarat (NG)	Increasing	Decreasing
Kachchh (KCT)	Increasing	Decreasing
Central Gujarat (CG)	Increasing	Decreasing
Eastern Tribal Belt (ETB)	Increasing	Constant
South Gujarat (SG)	Increasing	Constant
Saurashtra Hinterland (SH)	Increasing	Increasing
Saurashtra Coastal (SC)	Increasing	Increasing

Sources of Irrigation

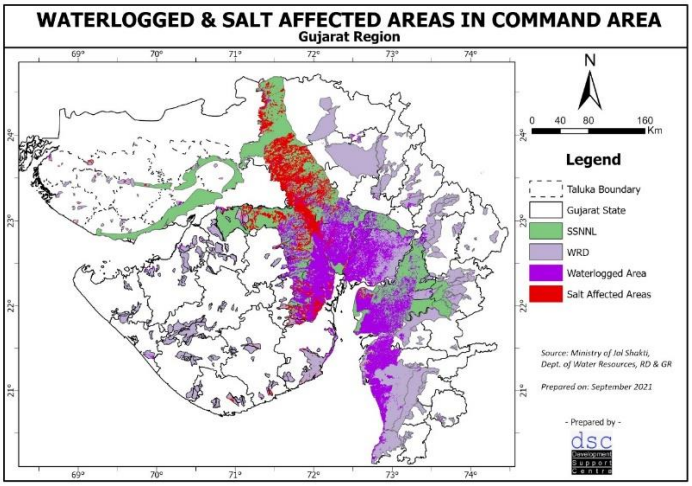
Canal and tubewell are the major sources of irrigation in the state. The temporal data (2008-09 to 2017-18) shows that the area under irrigation through tubewells has increased from 19.8 lakh Ha to 27.5 lakh Ha. i.e., 39%. The area under canal irrigation has increased from 11.21 lakh Ha to 18.13 lakh Ha. i.e., 62%. While the area under other sources such as tanks, open wells, check dams and Lift irrigation schemes has increased from 2.9 lakh Ha to 5.9 Lakh Ha. i.e., 103%. The area under the open well has decreased by 18%. The highest percentage decline of open well irrigation is seen in Kachchh (44%) and Central Gujarat (42%).

The map compares the canal-irrigated area with the tubewell-irrigated area for each district. As compared to other districts, Patan, Surendranagar, Ahmedabad, Kheda, Vadodara and Surat have high irrigation through both sources. Anand, Bharuch, Narmada, Tapi, Navsari, Valsad, Bhavnagar, Morbi, Mahisagar and Panchmahal have high irrigation through canals while Banaskantha, Sabarkantha, Mahesana, Gandhinagar, Aravalli, Chhota Udepur, Kachchh, Rajkot, Amreli and Devbhumi Dwarka have high irrigation through tubewells.

The districts that have low canal and tubewell irrigation areas are Jamnagar, Porbandar, Junagadh, Gir Somnath, Botad, Dahod and Dangs. These districts are mainly irrigated through other sources such as tanks, lift irrigation schemes, check dams and open wells.



Waterlogged and Salt-Affected Areas



Category-Wise Statistics of Land Degradation of Gujarat (2015-16)

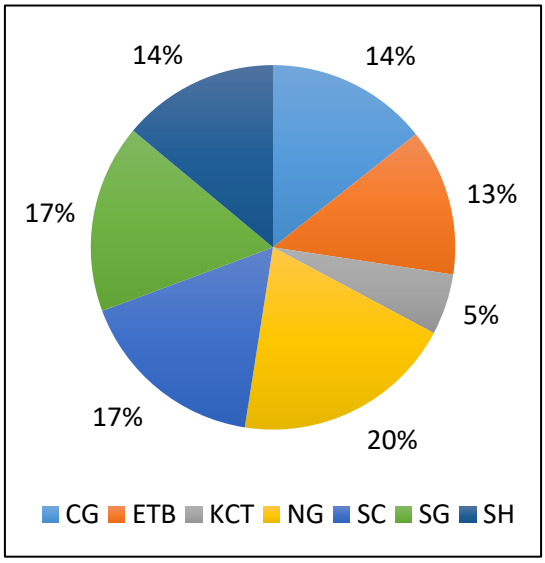
Class	Area (Ha)	% Of TGA
Acidification	0	0
Anthropogenic factors	34315	0.2
Glacial weathering	0	0.0
Others	437341	2.3
Salinization	3648338	19.4
Water-erosion	1557616	8.3
Waterlogging	82067	0.4
Wind-erosion	1275	0.0

It can be seen in North Gujarat that 16 % of the canal command area is salt affected. This could be due to the presence of Rann of Kachchh nearby and also due to the over-exploitation of groundwater. In South Gujarat, around 14% of the command area is under waterlogging. This could be due to the high irrigation supply to water-guzzling crops, excessive rainfall and the nature of the soil. In Central Gujarat, the waterlogged area covers about 15% of the command area and 8% of the area is salt affected. In Saurashtra Hinterland, around 31% of the command area is salt affected while 15% is waterlogged.

The above table indicates the status of land degradation due to natural and anthropogenic factors in Gujarat. It can be seen that about 19.4% of the total geographical area of Gujarat (188.11 Lakh Ha) is impacted by salinisation, while about 8.3 % is impacted by water erosion.

However, the data was from 2015-16. Thus, the actual affected may differ.

Water Harvesting Structures

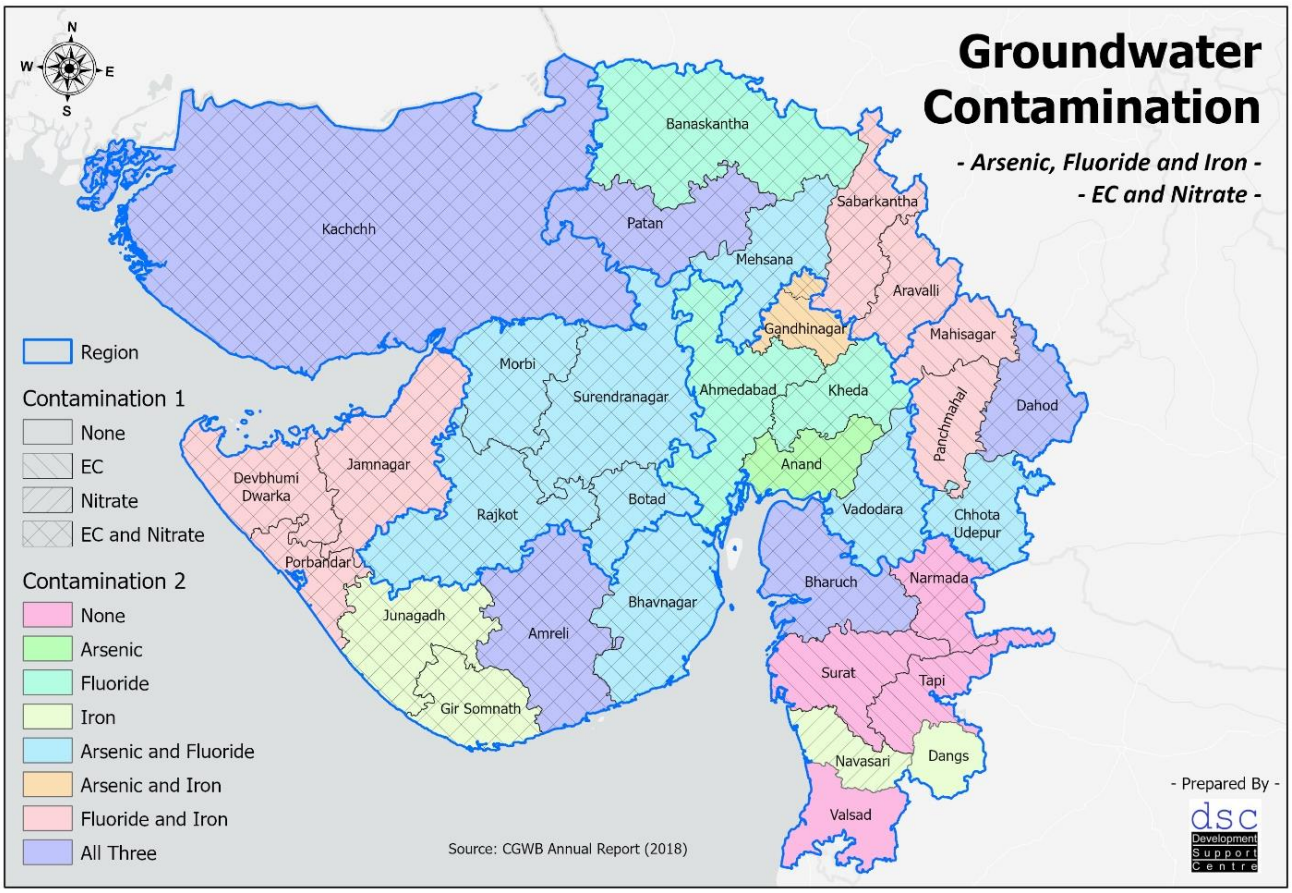


As per the data available from the WRD, about 5.55 lakh structures were constructed till March 2018. The highest number of check dams, bori bunds and farm ponds were constructed in Saurashtra Coastal, South and North Gujarat, respectively.

From the chart, the distribution of the number of structures is quite similar in all the regions except Kachchh. North Gujarat had the highest number of structures (20%), while the lowest number of structures were constructed in Kachchh (5%). However, as seen from the primary data of 227 structures in 12 watersheds, the maintenance of structures is an issue. It was found that **72% of** sampled structures in the Saurashtra coastal and **68%** of sampled structures in the Eastern Tribal Belt were not functional.

Groundwater Contamination

All the districts except Valsad and Dangs have contamination of Electrical Conductivity (EC) and Nitrate. Similarly, all districts except Narmada, Surat, Tapi and Valsad have Arsenic, fluoride or iron contamination. It is found that all five contaminations are seen in Kachchh, Patan, Amreli, Bharuch and Dahod.



Soil Quality

As per the secondary data, the nitrogen content is found to be generally low in all the regions of the state except Kachchh Hinterland and Saurashtra Coastal. In terms of phosphorus content, it is found to be medium in almost all the regions except Kachchh and Saurashtra coastal areas. Potassium is found to be high in most of the region except North Gujarat and the Kachchh coastal region.

Variable	CG	ETB	KCT	NG	SC	SH	SG
EC (Secondary)	< 1.0						
EC (mmhos/cm)	< 1.0	< 1.0	1.0 - 3.0	< 1.0	< 1.0	1.0 - 3.0	< 1.0
OC (Secondary)	> 75%	50 - 75%	> 75%	25 - 50%	> 75%	50 - 75%	50 - 75%
OC (%)	25 - 50%	25 - 50%	< 25%	25 - 50%	25 - 50%	25 - 50%	50 - 75%
P (Secondary)	> 60	28 - 56	28 - 56	28 - 56	> 60	28 - 56	28 - 56
P (Kg/Ha)	> 60						
K (Secondary)	150 - 300	150 - 300	150 - 300	150 - 300	150 - 300	180	325
K (Kg/Ha)	150 - 300	150 - 300	75 - 150	150 - 300	150 - 300	180	150 - 300

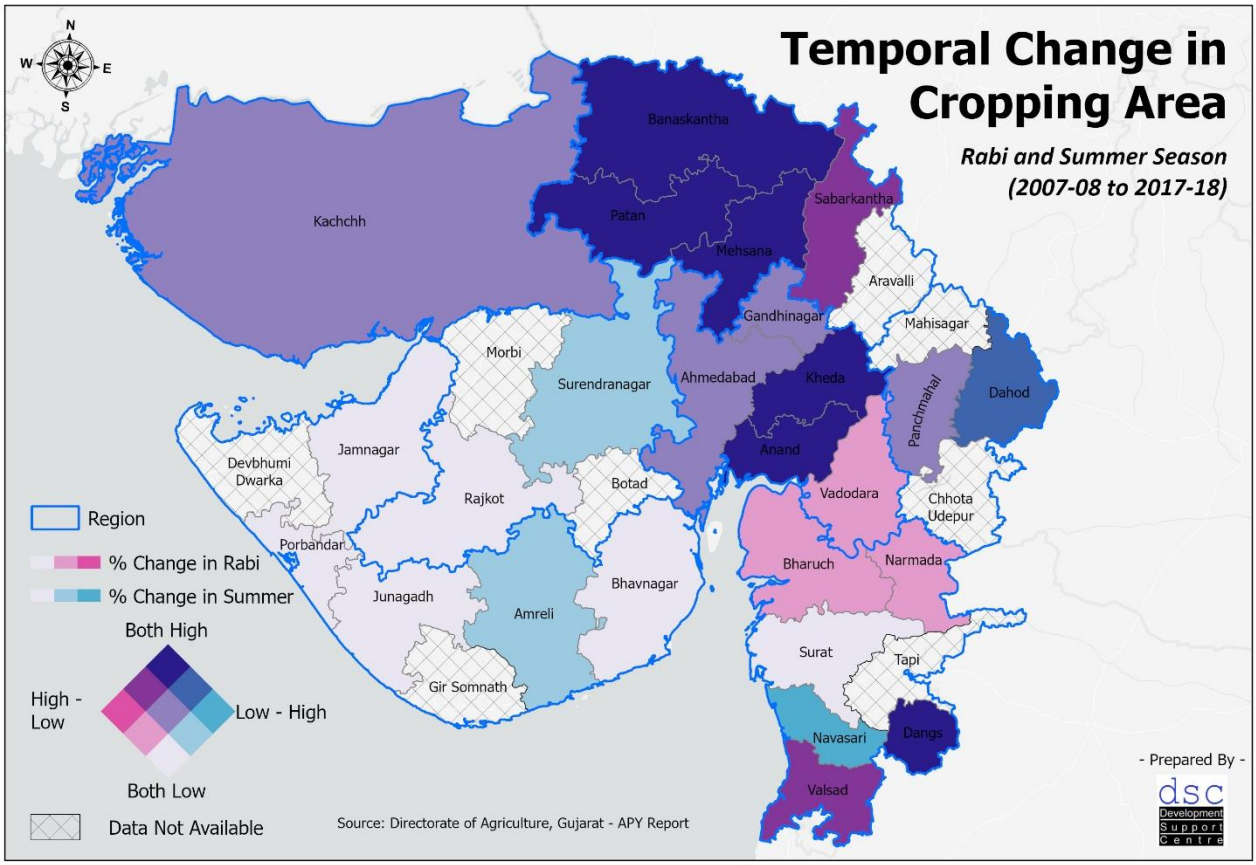
As compared with Secondary Data, primary data shows that EC content in Kachchh and Saurashtra Hinterland is higher while the organic carbon content is lower in all the regions except South Gujarat. The phosphorus content is found to be higher in all the regions and it was observed that the farmers were using much more chemical fertilizer than that recommended by experts. The potassium content was the same in all the regions except Kachchh where it is found to be lower.

Agriculture

The temporal change of the Cropping Area (2008-09 to 2017-18) was analysed for the Rabi and summer seasons as it has a direct impact on the agricultural water demand. The Kharif area has increased from 55 lakh ha to 59 lakh ha (7%), Rabi from 12 lakh ha to 15 (25%) lakh ha., in summer from 2.8 lakh ha to 3.3 lakh ha (18%) and in horticulture from 13 lakh ha to 18 lakh ha (38%).

Banaskantha, Patan, Mahesana, Kheda, Anand and Dang had a high growth (> 40%) of cropping area in both seasons. This could be due to the high growth of dairy as seen in the milk production map. Kachchh, Ahmedabad, Gandhinagar and Panchmahal showed a medium growth (20 to 40%) in both seasons. Sabarkantha and Valsad showed a high growth only in the Rabi season while Surendranagar, Amreli, Navsari and Dahod only in the summer season. Thus, it is seen that 50% of districts have a medium to high agricultural growth in the last decade.

A majority of districts have seen substantive growth in the horticulture area. Banaskantha, Surendranagar, Porbandar, Dahod, Narmada & Navsari have seen a growth of 60 to 90% while in Kachchh and Dangs it is more than 90%.



Actual Water Utilization vs. Ideal Crop Water Requirement

The study compared the actual water utilization by a farmer on the field with ideal water requirements as indicated in the State Irrigation Plan (2016-20). It shows that in the Kharif season, Kachchh has 30% of higher actual water utilization in Cotton and 100% in Groundnut. Central Gujarat has 118% of higher water utilization in Paddy. In Rabi Season, farmers of the Eastern Tribal Belt utilized 67% more water in Gram and 50% more water in wheat. In all the watersheds, farmers utilized more water in wheat, and it ranges from 25% in Saurashtra Hinterland to 170% in the North Gujarat region.

In Horticulture, farmers in South Gujarat utilized 25% of more water in bananas and 44% more water in Sugarcane. In Saurashtra, farmers used 30% more water for onions, while in Kachchh, farmers used 250% more water for Pomegranates. Overall, the farmers in Gujarat seem to be using **21%** more water than that recommended in the SIP.

Crop Classification based on Sales Price and water demand

The study tries to analyse the sales price of major crops in different regions (obtained from APMC 2021) with its water demand and correlates the same. The sales price (Rs/Qtl.) and water demand (MCM/Ha) were classified as high or low and thereafter each crop of the region was assigned to four different quadrants given below.

Quadrants	1st	2nd	3rd	4th
Region	**High Returns - High Water demand**	**High Returns - Low Water Demand**	**Low Returns - High Water Demand**	**Low Returns - Low Water Demand**
CG	Tobacco, Cotton	Castor, Gram, Cumin, Brinjal	Bajra, Paddy, Banana, Wheat	Cucurbits
ETB	Cotton, Mango	Tomato	Maize (Rabi), Wheat, Paddy, Banana	Maize (Kharif), Gram, Tur, Jowar, Okra
KCT	Groundnut (Summer), Pomegranate, Cotton, Date palm, Mango	Groundnut (Kharif), Castor, Sesame, Isabgul, Cumin, Coriander	Mustard, Wheat	Bajra, Jowar, Sorghum
NG	Cotton, Groundnut (Summer), Pomegranate	Groundnut (Kharif), Castor, Urad, Gram, Mustard, Green Gram, Cumin, Fennel	Wheat, Potato, Bajra	Jowar
SG	Groundnut(summer), Mango	Cotton, Gram, Urad, Green Gram, Okra, Brinjal,	Banana, Sugarcane, Paddy, Wheat	Maize, Cucurbits, Sapota
SC	Cotton	Gram, Green gram, Cumin, Coriander	Wheat	Groundnut (Kharif), Sesame, Sorghum, Bajra
SH		Coriander, Groundnut (Kharif), Gram, Sesame, Chilly, Cumin, Fennel	Garlic, Onion, Wheat, Cotton	Garlic, Cucurbits

Note- The returns for various are taken from the APMC (2021). However, the high price fluctuation in Agri-commodities and therefore the returns may vary each year.*

The results show that cereal crops such as wheat which is cultivated in all regions and paddy which is cultivated in South Gujarat, Central Gujarat and the Eastern Tribal belt fall under the 3rd quadrant. While pulses, spices and vegetables fall under the 2nd quadrant. Fruits and oil seeds have high returns and high-water demand while millets have low returns and low water demand.

The strategies for each quadrant could be as follows:

Q1 Quadrant: These are crops that have high returns which is the main deciding factor for the farmers, however, these crops are also having higher water demand. Therefore, demand-side management and reducing the crop water requirement through new varieties or practices such as mulching, micro-irrigation etc., may be promoted.

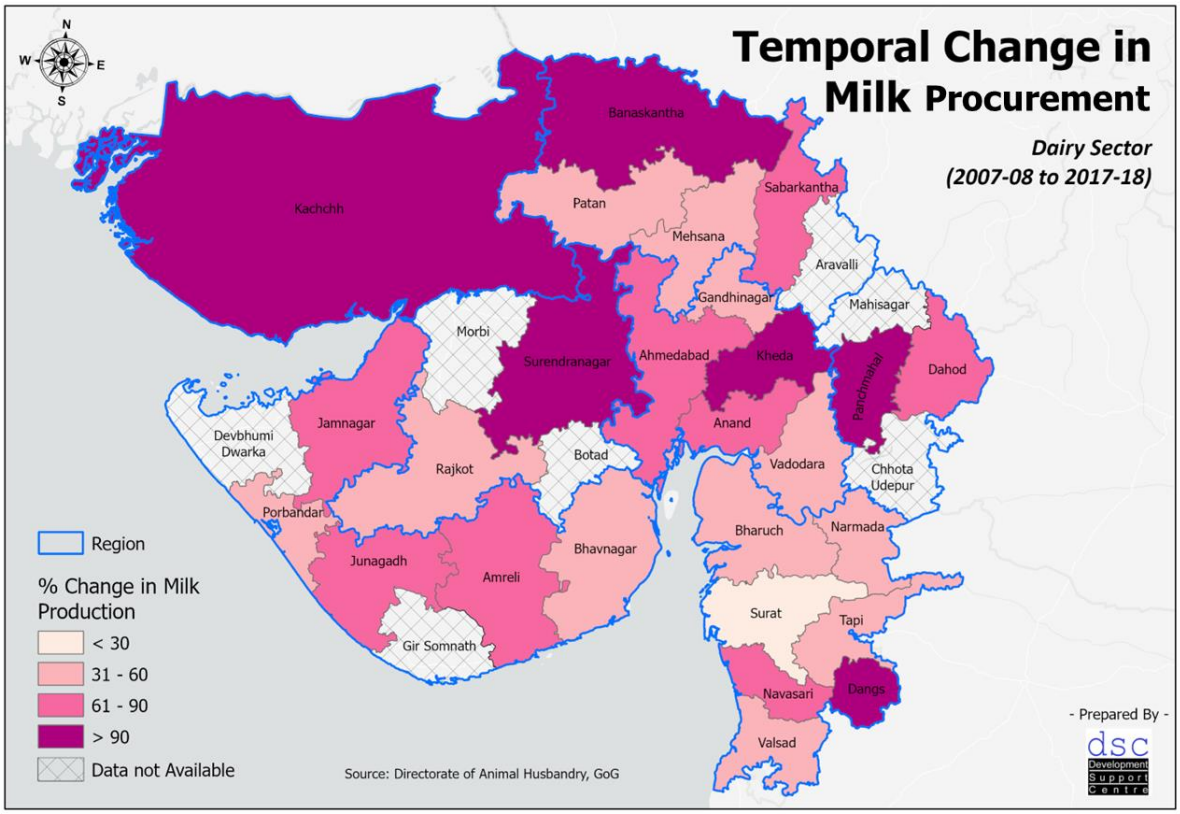
Q2 Quadrant: These are crops that are ideal in terms of high returns as well as low water demand. Thus, such types of crops can be promoted in the respective regions.

Q3 Quadrant: These are crops that have low returns and high-water demand. Thus, there is a need for crop diversification or to undertake measures for getting higher returns along with reducing water demand.

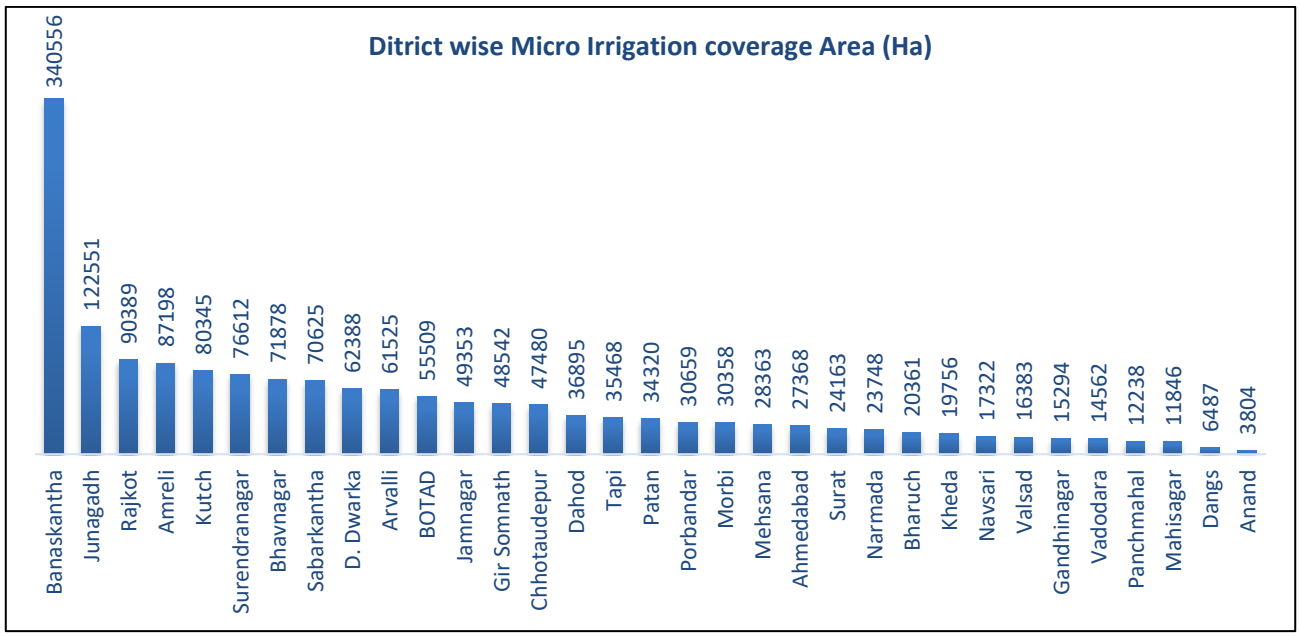
Q4 Quadrant: These are the crops that have low returns and low water demand. From a water security perspective, they are preferable. However, to increase the return on these crops, there may be a need for market linkages and value addition for better price realization.

Animal Husbandry

The temporal change in milk procurement (2008-09 to 2017-18) shows that several districts such as Kachchh, Banaskantha, Surendranagar, Kheda, Panchmahal and Dang have seen a growth of more than 90% in milk production in the dairy sector. While dairy contributes significantly to rural incomes, it could be a factor that contributes to groundwater depletion. Out of the 14 districts that have a demand–supply gap of more than 60%, 10 districts also have had more than 60% growth in milk procurement in the last decade.



Micro Irrigation in State



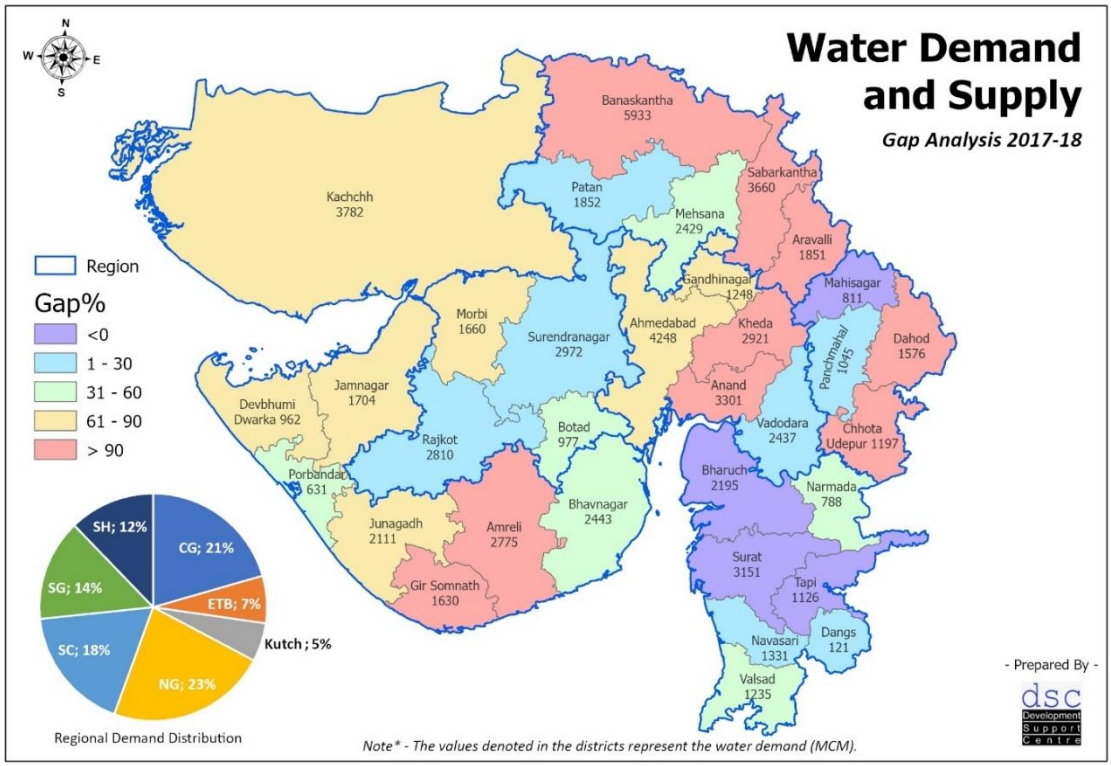
The Total area under Micro Irrigation in Gujarat was 16.7 lakh ha as per GGRC Report (2019-20). From the chart, it can be seen that Banaskantha has the highest irrigated area under micro-irrigation (3.4 Lakh Ha) among all the districts. However, in terms of the percentage of Micro irrigation vis a vis Grossed Cropped Area (GCA) of the district, it is found that Micro irrigation in Junagadh is 29% of GCA as compared to 25% of GCA in Banaskantha. Tapi and Sabarkantha have a 20% area under Micro Irrigation. The lowest percentage of Micro irrigation is found in Anand which is only 1% of the GCA. Though Banaskantha has a 25% area under Micro Irrigation, there does not seem to be much improvement in groundwater level as there is a substantive increase in the area under irrigation in Rabi and Summer.

Status of Village Institutions

Type of Village Institutions	No.	% Active
Milk Cooperative	18	100
Paani Samiti	9	78
Watershed Committee	3	67
Water Users Association	5	40
Total	35	

A total of 35 Village institution were identified from different regions of which a majority was Milk Cooperatives followed by the Paani Samities. All the Milk Cooperatives were quite active as compared to the other institutions. While only 40% of water user associations were functional. The reason is the preference for groundwater rather than canal water, especially in Central Gujarat.

Status of Water Demand & Supply



The overall demand for water from agriculture, animal husbandry, domestic and industry (for 2017-18) was considered for calculating the total water demand (MCM) of each district. The water supply (MCM) includes both surface water and groundwater. The gap between these two was analysed. The result shows that 9 out of 33 districts had a gap of more than 90% while 7 districts had a gap ranging from 60% to 90%. This indicates that the water demand in the majority of districts is much higher than the water supply. Therefore, urgent measures need to be taken on demand-side management as agriculture and animal husbandry contribute 92% of the total water demand in the state.

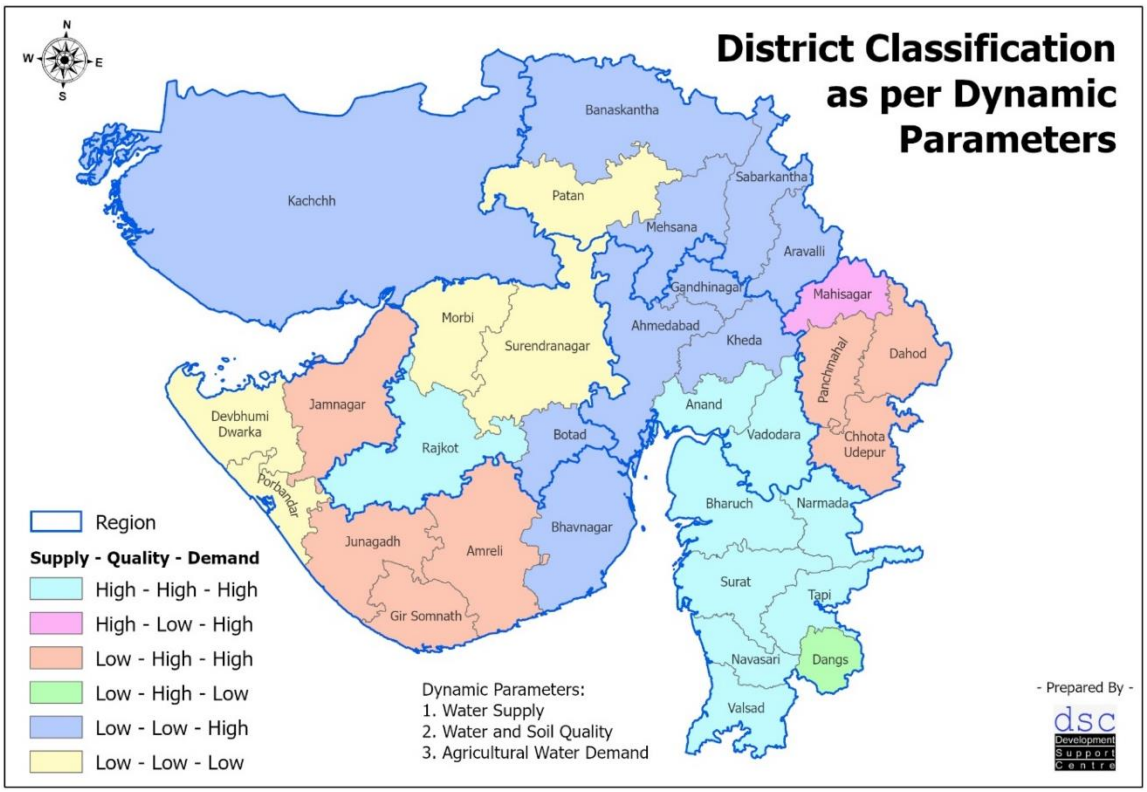
Emerging Scenario in the State

The analysis of fundamental parameters such as water and its quality, soil and its quality, agriculture and animal husbandry were summarized into the Water Supply, Soil Water Quality and Water Demand. These were correlated with each other to derive different scenarios.

The Water supply and demand (MCM/Ha) calculation has been carried out by normalizing the absolute values (in MCM) with the Grossed Cropped area in (Hectare). The average value of all 33 districts was considered a threshold level. Those districts that have higher values than the threshold was classified as high and those districts that had lower values than the state average were classified as low.

For Water & Soil Quality 3 variables were considered i.e., I) % District area having a TDS level of more than 1500 ppm. ii) % District area having Fluoride level more than 1.0 mg/l, iii) % District area having Nitrogen level less than 280 kg/Ha. The total of all three values was averaged. Thereafter the state's average was considered a threshold level. Those districts that have higher values than the threshold was classified as high and those districts that had lower values than the state average were classified as low.

It can be seen that the districts within each region show different types of characteristics that are shared with other regions. The worst-case scenario i.e., Low Water supply – Low Soil & Water Quality and High-Water Demand were observed in 10 out of 33 districts. These districts require focused interventions to enhance the water supply, improve water-soil quality, and reduce water demand.



Conclusions

- Water Management (surface and groundwater), soil health, agriculture and animal husbandry are interrelated. If water security issues have to be addressed, then one needs to intervene in all four aspects.
- Groundwater is a major source of irrigation across the state. Increase in the use of tube-well irrigation and a decrease in the use of open wells in the last decade. However, canal irrigation has also increased considerably during the same period.
- Water quality is an issue across a majority of the districts and therefore need for urgently intervening on the same in terms of policy and practice.
- Need for developing, repairing and maintaining local water bodies, making Panchayats accountable, and strengthening the village-level water governance institutions.
- Considerable increase in cropping area seen from 2008 – 2018 leading to high water demand in agriculture. Thus, need to promote millets and pulses rather than cereals such as wheat and paddy that have a considerable high-water footprint and low economic returns.
- The growth of dairy in the last two decades has been quite phenomenal, especially in North Gujarat, Kachchh and Eastern Tribal Belt. Thus, there is a need for interventions to reduce the water demand in the same.
- Transported water is both a boon and a bane as on the one hand it has increased the area under irrigation but in some regions caused water logging and salinity.
- Excessive use of water by farmers across all regions therefore an urgent need to promote water literacy, water measurement, water recycling and water recharging.
- Surface Irrigation Systems need to be more water efficient as we have a water deficit even in canal-irrigated areas such as Central Gujarat and North Gujarat. The state can no longer afford flood irrigation.
- Though MIS has been promoted in 16.7 lakh hectares it does not seem to have much impact on the water demand e.g., North Gujarat has the highest area under MIS, yet it is an over-exploited zone as per CGWB.
- Low Organic Carbon content is found in soils across all typologies due to excessive use of chemical fertilizers leading to decreasing soil health and groundwater contamination. Despite the Soil Health Card scheme, not much awareness was found amongst farmers.

Region-Specific Insights and Identification of Hotspots

Region	Aquifer setting and groundwater availability	Patterns and trends of demands	Sources of supply	Relationship with surface water development	Groundwater & Soil Quality
Kachchh	Local to regional aquifers, some with potentially large groundwater storage.	Rising demand, particularly in agriculture and the dairy sector shows a decadal growth of 94%. Also, possibly in the urban and industrial sectors as well. The % gap between Water supply and demand is 68%.	Groundwater is a major source of irrigation. Increased dependency on bore wells and tube wells, with a decline in dug well usage. The water availability is 0.0028 MCM/Ha which is lower than the state average of 0.0038 MCM/Ha.	No large command areas although the canal network is increasing (SSNNL).	Groundwater quality is of concern, particularly with high salinity levels and fluoride's emergence in samples. All five types of groundwater contamination (Arsenic, Fluoride, Iron, EC, and Nitrate) are seen in Kachchh. The soil quality indicates a low nitrogen level and a high Phosphorus and Potassium content.
North Gujarat (5 districts)	Largely thick, extensive alluvial aquifer systems with potentially large groundwater storage	Rising demand, especially in agriculture – rise in summer cropping accompanied by rising milk production. Banaskantha district shows a decadal growth of 160% and 106% in cropping areas in the Rabi & Summer Season. The dairy sector shows a decadal growth of 132% in Banaskantha & 70% in Sabarkantha District. The regional % gap between Water supply and demand is 119%. However, it is 145% in Banaskantha & 259% in Sabarkantha.	Tube wells and canals are on the rise; dug wells fading out on account of the progressive depletion of the shallow aquifers through long-term depletion. The water availability in all 5 districts is below the state average and Banaskantha has the lowest availability i.e., 0.0019 MCM/Ha.	Most command areas coincide with regional alluvial aquifers that can assimilate large volumes of induced recharge from leaky surface water systems	A combination of high nitrate, fluoride and salinity, especially as deeper sources of groundwater are tapped. All five types of groundwater contamination are seen in Patan. The soil quality indicates a low level of nitrogen and a moderate level of Phosphorus and Potassium content.
Central Gujarat (5 districts)	Dominantly alluvial aquifer systems – regional, thick aquifers with potentially large groundwater storage	Rising demand on account of the shift in cropping – more water-demanding agriculture - and expansion of irrigated areas, rising milk production and rapid expansion of urban centres. Anand shows a decadal growth of 108% in cropping areas in the Rabi Season. The dairy sector shows a decadal growth of 93% in Kheda & 75% in Anand District.	Tube wells in large numbers continue to pump groundwater even as canals and other surface water sources have risen; shallow aquifers in many areas are depleted over a longer period. The water availability in Kheda & Gandhinagar is below the state average i.e., 0.0028 MCM/Ha.	Groundwater dependency is likely to be high in command areas through the conjunctive use of canals and well water	High TDS in parts, Fluoride appearing but at the threshold of the permissible limit and Nitrates high in some areas (given the large storage in aquifers, values for all three may seem lower are the regional scales). The soil quality indicates a low level of nitrogen, moderate level of Phosphorus and high level of Potassium content.

Region	Aquifer setting and groundwater availability	Patterns and trends of demands	Sources of supply	Relationship with surface water development	Groundwater & Soil Quality
		The regional % gap between Water supply and demand is 80%. However, it is 123% in Anand & Kheda.			
Eastern Tribal Belt (4 districts)	Dominantly, low-storage, locally occurring crystalline aquifers with a mix of the other aquifers – alluvial, sedimentary; so, relatively limited groundwater storages with a high degree of variations in well-yields	Agricultural & dairy demand rising in patches raising concerns of potentially a more rapid decline of groundwater stocks in future. Dahod shows a decadal increase of 216% in cropping area in the Summer Season. The dairy sector shows a decadal growth of 100% in Panchmahal & 89% in Dahod District. The regional % gap between Water supply and demand is 88%. However, it is 234% in Dahod.	Dug wells tapping the shallow aquifers are still the dominant source although their numbers are declining at the expense of deeper tube wells and canal water. The Dahod has the lowest availability (0.0012 MCM/Ha) as compared to other districts.	Some parts with command areas of surface irrigation projects but many areas are still under groundwater irrigation	Fluoride and Nitrate – increasing trends are of concern while the TDS is also high in patches; some areas with all three contaminants. All five types of groundwater contamination are seen in Dahod. The soil quality indicates a low level of nitrogen, moderate level of Phosphorus and high level of Potassium content.
Saurashtra Hinterland (4 districts)	Mixed – basalts, alluvial and sedimentary aquifer systems, in juxtaposition and succession; a range of potential aquifer storages and therefore, iniquitous groundwater occurrence over the region	Cropping area increases, rise in groundwater demand and increased groundwater usage from deeper sources at the expense of shallow sources (dug wells). The dairy sector shows a decadal growth of 93% in the Surendranagar District. The % gap between Water supply and demand is 37%.	Increase in bore wells and tube wells, but dug wells still supply the larger input to the irrigated areas, especially as stand-alone sources in most of the western, central, and southern parts of the region. The Morbi, Surendranagar and Botad have low water availability (MCM/Ha) as compared to the state average.	Command areas of surface water projects in the northern and north-eastern parts; otherwise, a large groundwater dependency both as standalone sources and through conjunctive usage. Waterlogging is seen in command areas, especially in Surendranagar.	Fluoride and Nitrate are of concern although TDS over large regions is of moderate concentrations. The soil quality indicates a low level of nitrogen, moderate level of Phosphorus and high level of Potassium content.
Saurashtra Coastal (7 districts)	Basalts, limestones, and alluvial sediments imply a mixed system of aquifers – sometimes in juxtaposition and succession with each other; variable storages and well yields	Cropping areas have increased with an increase in agricultural water demand. The dairy sector shows a decadal growth of 60% to 90% in the Junagadh, Jamnagar & Amreli Districts. The % gap between Water supply and demand is 87%. However, it is 165% in Amreli, 129% in Gir Somnath & 88% in Junagadh.	Increase in bore wells and tube wells, but dug wells still support a substantial proportion of input to the irrigated areas. All the districts in the region have low water availability (MCM/Ha) as compared to the state average. Amreli has the lowest water availability i.e., 0.0018 MCM/Ha.	Patchy, local command areas imply a heavy reliance on groundwater that still constitutes the larger proportion of the water in irrigation	TDS and Nitrate are high in pockets; Fluoride generates within limits except in northern parts of Bhavnagar. All five types of groundwater contamination are seen in Amreli. The soil quality indicates a moderate nitrogen level and a high Phosphorus and Potassium content.

Region	Aquifer setting and groundwater availability	Patterns and trends of demands	Sources of supply	Relationship with surface water development	Groundwater & Soil Quality
South Gujarat (7 districts)	Contrasting aquifer systems – extensive, thick alluvial aquifers and low-storage, heterogeneous basalt aquifers	Rising demand in agriculture but also increasing demand for water from other sectors due to urban and industrial growth. Dangs shows a decadal increase of more than 100% in cropping area in the Rabi & Summer Season. While Valsad shows an increase of more than 100% in Rabi. The dairy sector shows a decadal growth of 200% in Dangs. The % gap between Water supply and demand is 10%. However, Valsad has the highest % gap i.e., 46%.	Data is unclear about sources, but field narratives show the growth in tube well and bore well numbers, although dug wells are still in operation; well data is possibly suppressed due to the dominance of command areas in the western part. All the districts in the region except Dangs (0.0014 MCM/Ha) have a much higher water availability (MCM/Ha) as compared to the State average.	Relatively limited groundwater share in agriculture due to the development of large-scale command areas but still high in areas not serviced by such commands (Western Parts)	TDS is higher in western parts; pocket, the local occurrence of Fluoride; Nitrates limited. All five types of groundwater contamination are seen in Bharuch. The soil quality indicates a low level of nitrogen, moderate level of Phosphorus and high level of Potassium content.

Region-Specific Water Management Strategies *(Note: These strategies will require policy support if they have to be effectively implemented)*

Regions	Managed Aquifer Recharge (MAR)	Supply-side interventions	Demand-side management
Kachchh	A combination of spreading techniques (watershed management) and injection techniques. Strategize MAR to address salinity ingress	Focus on improved quality of water and on improved soil-moisture capacities to reduce the risk from salinisation of soils	PGWM at different scales; adopting an ecosystem-based approach – attempt compensation for ecosystem services model in some areas
North Gujarat	A combination of spreading techniques (watershed management) – in the northern areas and injection techniques in large parts of the other areas with a specific focus on addressing salinity issues in areas bordering the Rann of Kutch	Improve efficiencies in pumping (reduce pumping rates) and long-term plans for reviving and restoring shallow aquifers that have either depleted or are saline	An aggressive, regional-scale PIM+PGWM campaign that combines efficient uses of groundwater and cropping pattern shifts – crop water budgeting based on large-scale groundwater balance estimates
Central Gujarat	Focus on injection techniques with the possibilities of using excess canal water in high-rainfall years for strategic groundwater recharge to aquifers	Improve efficiencies in pumping (reduce pumping rates) and long-term plans for reviving and restoring shallower aquifers that have either depleted or are saline; develop soil drainage and soil improvement programmes in areas prone to water-logging and soil salinisation	An aggressive, regional-scale PIM+PGWM campaign that combines efficient uses of groundwater and cropping pattern shifts – crop water budgeting based on large-scale groundwater balance estimates
Eastern Tribal Belt	Watershed management (spreading) – also consider reviving springs in some of the eastern high grounds	Focus on improving the groundwater quality regime by strategic tapping of aquifers with better groundwater quality and treatment and management of water with high Fluoride content	Status quo on sustainable cropping and agriculture with key elements of PGWM (in combination with PIM in the command areas) at local scales
Saurashtra Hinterland	Watershed management (spreading techniques) with a few areas for injection techniques; spring shed management especially in the central highland region that also includes the Gir forest sanctuary	Protect and revive shallow aquifers and strategize efficient pumping of shallow aquifers; develop soil drainage and soil improvement programmes in areas prone to waterlogging and soil salinisation	Conjunctive use of surface water and groundwater through PIM and PGWM while ensuring crop water budgeting, especially over areas underlain by basalt aquifers; focus on ecosystem-based strategies
Saurashtra Coastal	watershed management (spreading techniques) and strategic injection recharge + *revival of the older watershed management projects through large-scale maintenance and repair of structures.* Specific focus on MAR to address salinity ingress	Protect and revive shallow aquifers and strategize efficient pumping of shallow aquifers; develop programmes on arresting and protecting against salinity ingress into coastal aquifers	PGWM is the key element for demand-side management of groundwater, especially through crop water budgets that are based on aquifer-based groundwater balance estimates from season to season
South Gujarat	The full combination of watershed management – MAR through spreading including a revival of springs in the Western Part & injection recharge in the northern alluvial parts	Protect and revive shallow aquifers and strategize efficient pumping of shallow aquifers; watershed management in the southwestern areas; develop soil drainage and soil improvement programmes in areas prone to waterlogging and soil salinisation	Conjunctive use of surface water and groundwater through PIM and PGWM while ensuring crop water budgeting, especially over areas underlain by basalt aquifers

Strategies & Policy Recommendations

Over the last decade (2008-2018), there has been considerable growth in agriculture, dairy and irrigation infrastructure in the rural areas of Gujarat. Agriculture and animal husbandry have significantly contributed to enhancing the incomes of rural communities and state revenue. However, this agriculture and dairy growth may not be sustainable in the near future as it has led to groundwater depletion, an increasing gap between supply and demand for water and impacted the soil and water quality. Water Management (surface and groundwater & water quality), soil health, agriculture and animal husbandry are interrelated. As per Dr Mihir Shah, we can no longer continue to have a "hydro-schizophrenic" approach towards water management.

RECOMMENDATIONS

Water Supply

i. Urgent initiation of the watershed management projects through large-scale maintenance and repair of structures and artificial recharge especially in Jamnagar, Porbandar, Junagadh, Gir-Somnath, Botad, Dahod and Dangs which are mainly dependent on tanks, open wells, check dams and lift irrigation.

ii. Promote an integrated approach to Water Resource Management in all the canal commands and watersheds in the state. This includes surface water management, Participatory Groundwater Management and Demand side management.

iii. Currently, seven districts i.e., Ahmedabad, Gandhinagar, Banaskantha, Sabarkantha, Patan, Mehsana and Kachchh are covered under the Atal Bhujal yojana in the state based on the state of groundwater exploitation. There is also a need to include Jamnagar, Junagadh, Amreli, Gir Somnath, Dahod, Chhota Udepur, Anand and Kheda as they have more than a 60% gap between the supply and demand of water and a high dependency on the shallow aquifer for irrigation.

Water Demand

i. Provide policy & price incentives for low water-guzzling crops such as millets (especially in the Eastern Tribal Belt), pulses, and spices.

ii. Reduce water consumption in Dairy by promoting low water requirement fodder crops such as millets, reduce water use in milk processing and introduce improved cattle breeds as done by Banas dairy.

iii. Enhancing water literacy by building local cadres from the community, especially the youth as Bhujal / Sujal Jankars so that they can monitor groundwater, help the Panchayat to carry out water security plans and conduct water audits.

iv. Strengthen the village institutions such as Paani Samities and WUAs and pilot a more holistic Sankalit Jal Vyavasthapan Samities that works on all water resources and all water uses in the village. Incentivize the Panchayats for repair, maintenance and management of water harvesting structures. Enhance the participation of women in decision-making and water governance at the village level.

Water and Soil Quality

i. In the long run, prevention of water contamination is the only option for the sustainability of water quality solutions. Focus on behaviour change communication with policy support and incentives would help. Incentivize optimum water use through a pricing mechanism and incentivize the Gram Panchayats for grey water treatment and recycling.
ii. Need to identify hotspots of water contamination at different scales. Zone out the contaminated zones and the safer zones and protection of safe water zones as "Safe water aquifer sanctuaries" Avoid the transfer of contaminants from the hotspots to the sanctuaries.
iii. Promote responsible/natural farming on large scale to reduce the use of chemical inputs thereby improving soil health and also reducing water contamination.

Scope for further studies

- Study actual crop water utilization, yield and economic returns to farmers with large samples from the regions of Gujarat
- Examine the role of intensification of dairy production in deepening the groundwater crisis
- Study on water quality and its impact on livelihoods in identified hot spots
- Study of the impact of Micro Irrigation Systems on water demand and comparison of installed v/s actual use
- Study the current interventions for the treatment of water-logged areas
- Study on post-project management of watershed and water harvesting structures and role of Panchayat

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"This study is truly a magnum opus. It is voluminous work that encompasses several dimensions and offers a geographically textured analysis of the interaction between agriculture, water and soil. It is laborious and patient work that has engaged a large group of researchers/practitioners. Its main contribution in my view is in enormous effort devoted to data mobilization from myriad sources and their exploration. This is a truly excellent sourcebook and will be found useful by a variety of players. It has some lovely and striking GIS maps. I also think that this report is an excellent water-soil-agriculture situation analysis. I hope DSC will keep building on this and keep doing more such work".

Dr Tushaar Shah
International Expert on Water Management

GLIMPSES OF THE STUDY

Groundwater Monitoring

Survey of Water Harvesting Structures

PRA Exercises with women

Community Consultation Workshops

Water Quality Testing

Survey of Cropping patterns and issues in agriculture

RESEARCH TEAM

PROJECT MANAGEMENT UNIT

A Project Management Unit (PMU) was formed to design and execute the study. It had a multi-disciplinary team with expertise in GIS, Water Resources Development, Agriculture and Data Management. The PMU team is comprised of the following individuals:

Name	Designation
Mr. Mohan Sharma	Water Resources and Irrigation Management Specialist (Project Director)
Mr. Sachin Oza	Institution Development & Documentation Specialist (Project Anchor)
Mr. Saurin Mehta	Lead Researcher – GIS Solutions Architect
Mr. Kunj Shethiya	GIS Specialist
Mr. Kaushal Gadariya	Soil and Water Conservation Engineer and GIS Specialist
Mr. Richard Manu	Agriculture Expert and Field Research Coordinator
Mr. DeepakKumar Yogi	Documentation Expert and Field Research Coordinator
Mr. Pranav Chauhan	Water Resource Expert
Mr. Meet Thakar	MIS Expert

FIELD RESEARCHERS

The PMU hired field researchers for the primary data collection from different demarcated watersheds in each of the respective regions. They were also involved in soil and water quality testing of sample farmers in the watershed and conducting regional workshops for the community.

Region	Name of Field Researchers
North Gujarat	Mr. Raghu Desai
	Mr. Gopal Jayswal
Central Gujarat	Mr. Anand Shah
	Mr. Chandrapalsinh Rathod
South Gujarat	Mr. Jaideep Gamit
	Mr. Dharmesh Patel
Saurashtra Hinterland	Mr. Hitesh Chavda
	Mr. Rajnikant Rathod
Saurashtra Coastal	Mr. Sunil Kher
	Mr. Budha Bamaniya
Kutch Hinterland & Coastal	Mr. Velji Goradiya
	Mr. Ravi Kumar
Eastern Tribal Belt	Mr. Rishi Patel
	Mr. Sukram Ninama